RANGE MANAGEMENT IN THE CHAPARRAL TYPE AND ITS ECOLOGICAL BASIS:
The Status of Our Knowledge

Dwight R. Cable

Rocky Mountain Forest and
Range Experiment Station
Forest Service
U.S. Department of Agriculture
Fort Collins, Colorado 80521

USDA Forest Service
Research Paper RM-155

October 1975

Abstract

Cable, Dwight R.
1975. Range management in the chaparral type and its ecological basis: The status of our knowledge. USDA For. Serv. Res. Pap. RM-155, 30 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Chaparral in Arizona is used far below its potential. Conversions to grass can greatly increase water and grass production, and improve wildlife habitat. Management options include conversion to grass, maintaining shrubs in a sprout stage, changing shrub composition, reseeding, and using goats to harvest shrub forage.

Keywords: Chaparral, range management.

USDA Forest Service
Research Paper RM-155

October 1975

RANGE MANAGEMENT IN THE CHAPARRAL TYPE AND ITS ECOLOGICAL BASIS: The Status of Our Knowledge

Dwight R. Cable, Principal Range Scientist
Rocky Mountain Forest and Range Experiment Station[1]

[1]Central headquarters is maintained at Fort Collins, in cooperation with Colorado State University; author is assigned to the Station's Research Work Unit at Tucson, in cooperation with the University of Arizona.

CONTENTS

Figure 1.—Chaparral type in Arizona (in white), with locations of major experimental areas (adapted from Ariz. Agric. Exp. Stn. Bull. A-45).

RANGE MANAGEMENT IN THE CHAPARRAL TYPE AND ITS ECOLOGICAL BASIS:
The Status of Our Knowledge

PHYSICAL CHARACTERISTICS OF THE CHAPARRAL TYPE

Geographic

The chaparral type of the southern Rocky Mountains is located almost exclusively in Arizona, where it occupies a relatively narrow, discontinuous band of broken, rough terrain. This band extends in a southeast-to-northwest direction through the central part of the State, just south of the Mogollon Rim (fig. 1).

The total acreage in the chaparral type has been reported variously between 4 million (Hibbert and Ingebo 1971) and about 5.8 million acres (Nichol 1952), apparently depending largely on where boundaries are set as the type intergrades with more mesic and xeric species at the upper and lower elevational boundaries, and with the intensiveness of type delineations within the main body of the chaparral area itself. Probably the most authoritative single map of the chaparral type in Arizona was published by the Arizona Agricultural Experiment Station (1965), based on data from the USDA Forest Service, USDI Bureau of Land Management, USDI Bureau of Indian Affairs, USDA Soil Conservation Service, and original mapping by R. R. Humphrey. A dot-grid acreage determination of the chaparral type as shown on this map indicates only about 3.2 million acres, probably a rather realistic figure.

Physiographically, the chaparral type occupies portions of the Transition Zone, south of the Plateau Province (which is bounded on the south by the Mogollon Rim) and the Mountain Region of the Basin and Range Province to the south (Wilson 1962). Most of the central portion of the chaparral type (eastern Yavapai and northwestern Gila counties) is in the Transition Zone, which structurally resembles the Plateau Province to the north in that its strata (predominantly sedimentary and volcanic rocks) for the most part lie essentially flat, only moderately affected by faulting and erosion. In most of the remainder of the chaparral type, the Mountain Region, the strata have been more intensely deformed by faulting, volcanism, erosion, and sedimentation.

Topography in the chaparral type consists largely of isolated mountain ranges cut by steep-walled canyons and gorges (Sellers 1960). The area is mostly drained by the Gila River and several of its tributaries (the Verde, Salt, Agua Fria, and Hassayampa). Flows of the Salt, Verde, and Gila Rivers are collected by the reservoirs within the general area. The westernmost portion of the chaparral type drains westward through the Bill Williams River directly into the Colorado River.

Elevations within the chaparral type vary mostly between 3,000 and 6,000 feet (Hibbert and Ingebo 1971), although the main mountain peaks rise to from 7,500 to 8,000 feet (Sellers 1960).

Climatic

Precipitation is concentrated largely in two distinct periods in the chaparral type, as in the rest of the State. This climatic aspect of Arizona's chaparral type differs markedly from that of the other major world chaparral communities, whose climates are characterized by wet, mild winters and long, hot, dry summers (Biswell 1954).

The summer rains fall primarily in July and August, the two wettest months of the year. The winter precipitation season extends from December through the middle of March. Average annual precipitation in the "central" section of Arizona (whose exterior boundaries agree very closely with those of the chaparral type) is 18.87 inches, of which

an average of 48 percent falls between May and October (Sellers 1960). Annual precipitation ranges between about 15 and 25 or more inches. Average depth of snowfall varies within the type from about 4 to 25 inches per year.

Summer precipitation comes almost entirely from the Gulf of Mexico to the southeast, and falls in convective thunderstorms when the moist, tropical air flows over strongly heated mountainous terrain. In perhaps one year in five, a late August or September tropical hurricane off the west coast of Mexico will produce a deep surge of moist tropical air into the State from the southwest, yielding flood-producing rains.

Arizona's winter precipitation is associated with large-scale cyclonic storms originating over the Pacific Ocean, which are occasionally displaced southward from their normal eastward path. Because of the more complicated synoptic situations required to produce winter precipitation over Arizona, cool-season precipitation is considerably more variable from year to year than warm-season (Sellers 1960). The two precipitation seasons are separated by dry periods in spring and fall, the spring drought (May and June) being particularly severe.

Average daily maximum temperatures for the hottest months in the chaparral type (usually July) vary from about 88° to 98°F, with absolute maximums from 99° to 110°F (average daily minimums for the same month vary from 52° to 68°F). Average daily minimum temperatures for the coldest month (usually January) vary from 20° to 31°F, with absolute minimums from -21° to 1°F (average daily maximums for the same month vary from 50° to 57°F). Average temperatures in summer vary rather uniformly with elevation, decreasing about 1°F for each increase of 235 feet in elevation (Sellers 1960). Winter temperatures are not so closely correlated with elevation.

Geologic and Edaphic

All three major classes of rocks are represented in the parent material rocks of the chaparral type (Kearney and Peebles 1951, Schmutz and Whitham 1962, Pase and Pond 1964, Saunier 1964, Kemp 1965):

Igneous rocks: granites, basalt, diabase, granodiorite, quartz, diorite, gabbro, lavas.
Sedimentary rocks: shales, limestones, sandstones.
Metamorphic rocks: gneisses, schists, quartzite.

Sedimentary rocks predominate in the central portion of the chaparral type (Transition Zone); granite is a prevalent parent material over much of the rest of the type (Rich 1961).

Soils developed from granitic parent materials are mostly of sandy texture, relatively shallow, and low in fertility. Lava and basalt substrata, however, give rise to fine-textured soils (Saunier 1964) as also do shales, sandstones, and limestones at higher elevations (Pase and Pond 1964). Along the drainages, deep alluvial sandy loams are common (Schmutz and Whitham 1962). Because chaparral shrubs require deep rooting for optimum development, the presence of such shrubs on shallow soils indicates deep fracturing and weathering of the parent material. Shrub roots can obtain water that penetrates below the reach of most grasses and forbs (Saunier 1964, Pase and Fogel 1967, Suhr 1967, Hibbert and Ingebo 1971, Ingebo 1971).

The wide range in climatic, topographic, geologic, and edaphic conditions within the area occupied by the chaparral type produces a variety of vegetation types: chaparral, oak woodland, pinyon-juniper woodland, and grassland. Their particular distribution undoubtedly depends in part on combinations of environmental factors that slightly favor (more nearly meet the physiological requirements of) one kind of vegetation over another. The precise limits of the environmental factors within which one type of vegetation is favored over another are not known. However, some generalizations have been made, based largely on observation. McGinnies et al. (1941) discussed this situation as it applies to the Arizona chaparral type as follows:

> Oak woodland is similar to chaparral in its requirements, but is usually found where moisture conditions are more favorable. The requirements of pinyon-juniper woodland do not appear to be as definitely set except that the major species successfully withstand much lower temperatures than those of the broadleaf woodland type.
>
> In many places in the Southwest these vegetation types are found growing under conditions near the extremes of their tolerance. For example, chaparral will be found where the precipitation is approximately equally divided between summer and winter. Grassland is also found under similar conditions, and in many places these two types enter into direct competition. Under such conditions other factors may determine the ultimate vegetational development. Usually on the coarser more open soils, particularly on steep slopes, chaparral will be found, while on the heavy soils and more level ground grassland will dominate, but the increase or decrease in intensity of other factors may tend to throw the vegetation either towards brush or towards grass. Thus grazing, which is more severe in its effect on grass, favors the invasion of chaparral even on heavier soils and where the climate is definitely more favorable toward grass.

Erodibility of chaparral soils varies with the parent material from which the soils developed. Fletcher and Beutner (1941) reported that the "erodibility integral" (a rating based on "erosion-against-slope" curves) for central Arizona soils above 3,500- to 4,000-foot elevations is low for soils developed from quartzite, basalt, and limestone (EI = 3.7, 3.4, and 3.2, respectively), but is three times as high for soils developed from granite (EI = 9.9).

ECOLOGICAL AND PHYSIOLOGICAL CHARACTERISTICS OF THE BIOTA

Systematics

Taxonomic

Plants.—At least 50 shrub species have been reported in the chaparral type, although Pond and Bohning (1971) state that fewer than 15 are really important from either a density or animal-preference standpoint. Nichol (1952) reports that on many areas the stand is a heterogeneous association, but that more often one or two species dominate the type to give it a specific character. All authorities agree that shrub live oak[2] is the most abundant element of the chaparral (Kearney and Peebles 1951) (fig. 2). The diversity in stand composition has been ascribed to differences in soils, slopes, elevations, exposures, and precipitation (Nichol 1952, Pond 1964).

The upper and lower boundaries of the chaparral exhibit an intermixture of types. At the lower elevations, the chaparral may occur on north-facing slopes with desert shrubs on the south-facing slopes (Swank 1958, Rich 1961), or the chaparral may join with semidesert grassland (Pase 1966). In such situations shrub live oak is usually the dominant, with small amounts of skunkbush sumac, catclaw acacia, catclaw mimosa, nolina, sugar sumac, or California

[2]*Common and botanical names of plants mentioned are listed at the end of this Paper.*

Figure 2.—Chaparral type at approximately 5,000 feet elevation southwest of Prescott; predominantly shrub live oak; loose granitic soil; annual precipitation about 17 inches.

jojoba, and often occasional semidesert shrub species (Swank 1958, Rich 1961, Pase and Johnson 1968) (fig. 3). At the upper boundaries, the chaparral frequently extends as an understory into the fringes of the ponderosa pine or pinyon-juniper types. In these situations species such as true mountain-mahogany, Emory oak, Arizona white oak, Wright silktassel, deerbrush, Pringle manzanita, and one-seed juniper may be associated with the dominant shrub live oak (Nichol 1952, Swank 1958, Pase 1966, Pase and Johnson 1968) (fig. 4).

Within the midportion of the type, differences in shrub composition on north and south exposures may indicate relative preferences of the various

Figure 3.—Low-elevation (3,800 feet) chaparral on north slope at Summit watersheds, Tonto National Forest; loose granitic soil; annual precipitation about 15 inches [redacted].

Figure 4.—High-elevation chaparral on Tonto National Forest with scattered Emory oak. Understory grasses are primarily side-oats and hairy gramas, and curly mesquite.

species for more mesic or xeric conditions, respectively. Kemp (1965) provides such a comparison for two areas on the Sierra Ancha Experimental Forest at about 5,000 feet elevation and 23 to 25 inches annual precipitation. Slopes averaged between 30 and 50 percent. Species preferring the south exposure were catclaw acacia, pointleaf manzanita, and nolina. Those preferring the north exposure were skunkbush sumac, hollyleaf buckthorn, Arizona white oak, pinyon pine, and to a lesser extent, true mountainmahogany, and desert ceanothus. Shrub live oak and Wright silktassel were equally abundant on both exposures.

Soil type preferences have not received much investigation, although one-seed and Utah junipers and cliffrose are reported to be particularly abundant on soils derived primarily from limestone near the upper transition (Swank 1958). Darrow (1944) notes that pointleaf manzanita occurs most frequently on granitic soils, and that hairy mountainmahogany often comprises pure stands on limestone slopes above 5,000 feet elevation in Chochise county. Soil differences are also reported as responsible for the separation of chaparral and juniper under otherwise similar environmental conditions, with chaparral occupying coarse-textured soils derived mainly from granite, and juniper occupying fine-textured soils derived from basalt, limestone, and quartzite (Hibbert et al. 1974).

Composition reported for specific shrub stands indicates that (1) shrub live oak comprises from 45 to 80 percent of the total shrub cover on most sites, (2) usually only one or two other shrub species contribute over 10 percent of the total shrub cover, (3) between 7 and 10 individual shrub species are present on any given area, and (4) total shrub crown varies between about 25 percent at lower elevations with lower precipitation, and 80 percent, at higher elevations with higher precipitation. In view of the literature references to true mountainmahogany as favoring the higher elevations of the chaparral type, its relative abundance on several areas in table 1, even at the Summit watershed at 3,700 feet elevation and 15 inches annual precipitation, is somewhat unexpected.

A detailed listing of plant species in the chaparral type on the Sierra Ancha Experimental Forest included 37 species of trees and shrubs, of which four were listed as "very abundant" (Pase and Johnson 1968). Also listed were 139 forbs and 30 grasses.

Few understory forbs and grasses are present at the upper elevations of the chaparral type at Sierra Ancha where shrub crown cover is high. At the lower elevations, however, where shrubs are more scattered, understory grasses and forbs are fairly common, especially annuals (Pase and Johnson 1968). Scarcity of understory plants in denser chaparral stands in other parts of the type has also been noted by Saunier (1964), Pase and Ingebo (1965), Pase (1966), and Ingebo (1971).

Tiedemann and Schmutz (1966) report from 3 to 8 percent ground cover of forbs on chaparral areas east of Prescott (purslane was the dominant) and from 0 to 2 percent ground cover of grasses, primarily Lehmann lovegrass and side-oats grama. Broom snakeweed was the dominant half-shrub, with lesser amounts of Wright eriogonum and toadflax penstemon (total half-shrub densities 2 to 5 percent).

Black, hairy, and side-oats gramas and threeawns may dominate the herbaceous cover at lower elevations where chaparral borders on semidesert grasslands (Pase 1966). Swank (1958) notes that side-oats grama is particularly abundant at the higher elevations where the chaparral intergrades with pine forest or juniper-grassland types. He also notes that red brome (= foxtail brome, an annual grass) is the most abundant herbaceous species at lower elevations in the Three-Bar area, with spurges and threeawns also common, and that on heavily grazed chaparral areas broom snakeweed often forms a nearly pure understory.

In the southeastern part of the type (Cochise county), Darrow (1944) notes that bullgrass, deergrass, little bluestem, side-oats grama, and plains lovegrass are common in the chaparral above 5,000 feet, and side-oats and hairy gramas, bluestem, and green sprangletop are common at the lower elevations.

At Tonto Springs, west of Prescott (5,000 feet elevation) common half-shrubs were broom snakeweed and Wright eriogonum, and common perennial grasses included blue, black, hairy, and side-oats gramas, several threeawns, squirreltail, and longtongue mutton bluegrass (Pond 1968c).

Animals.—The principal game animal in the chaparral type is the mule deer, although peccaries are common at lower elevations. Gambel quail are also common at lower elevations (Rich and Reynolds 1963). Coyotes, bobcats, badgers, foxes, and skunks also inhabit the type, depending on the availability of small rodents for food, and whitetail deer are common in the higher areas (Nichol 1952, McCulloch and Urness 1973). The chaparral is also an important type for the black bear. Densities of mule deer are estimated to vary from 4 to 5 per square mile in stands of shrub live oak and skunkbush sumac to 20 to 30 per square mile at higher elevations where birchleaf mountainmahogany, desert ceanothus, and hollyleaf buckthorn are abundant (Swank 1958).

A detailed listing of vertebrates in the chaparral type on the Sierra Ancha Experimental Forest includes 83 species, broken down as follows (Reynolds and Johnson 1964):

Table 1.--Elevation, precipitation, and percent composition of shrub crown cover at several undisturbed locations[1] in the chaparral type

Elevation, precipitation, and shrub species	Sierra Ancha Experimental Forest (1)	(2)	(3)	Three Bar watersheds (4)	(5)	Copper Creek (6)	Bloody Basin (7)	Summit watersheds (8)	Southern Mingus Mountain area, east of Prescott (9)	(10)	(11)	(12)
						Feet						
Elevation	4700	4900	5100	4500	3500	4000	3600	3700	----4900 to 5350----			
						Inches						
Annual precipitation	21	23	25	23	26	17	15	15	15	15	15	15
						Percent						
Shrubs:												
Shrub live oak	72	53	49	45	26	60	42	59	60	80	75	67
Pointleaf manzanita	--[2]	1	25	--	--	--	--	--	6	T	5	7
Hairy mountainmahogany	--	--	--	--	--	--	--	--	6	1	4	1
True mountainmahogany	T	13	8	22	--	10	--	31	--	--	--	--
Desert ceanothus	14	8	3	1	--	4	--	--	1	2	1	1
Hollyleaf buckthorn	7	6	1	9	--	1	--	--	--	T	--	--
Wright silktassel	1	9	8	1	--	--	--	--	--	--	--	--
Skunkbush sumac	6	7	T	1	--	20	--	--	24	14	16	22
Sugar sumac	--	--	--	4	--	1	--	--	--	--	--	--
Catclaw acacia	T	1	1	11	4	42	--	--	--	--	--	--
Palmer oak	--	--	--	16	--	--	--	--	--	--	--	--
Nolina	--	1	5	--	--	--	--	--	--	--	--	--
California jojoba	--	--	--	--	26	--	--	--	--	--	--	--
Pinyon pine	--	T	--	--	--	--	--	--	--	--	--	--
Arizona white oak	--	2	--	--	--	--	--	--	--	--	--	--
Jumping cholla	--	--	--	--	16	--	--	--	--	--	--	--
Datil yucca	--	--	--	--	5	--	--	2	--	--	--	--
Palo verde	--	--	--	--	11	--	--	--	--	--	--	--
Velvet mesquite	--	--	--	--	5	--	--	--	--	--	--	--
Mescat acacia	--	--	--	--	--	--	--	8	--	--	--	--
Others	--	--	--	--	--	--	14	--	--	--	--	--
Total crown cover	57	81	82	70	--	50	12	25	36	37	36	28

[1]Locations and authors of reports:
(1) -Natural Drainages (unpublished data 1956)
(2,3)-(Unpublished data 1965)
(4) -NW of Roosevelt Reservoir (unpublished data 1956)
(5) -(Swank 1958)
(6) -NW corner of Tonto NF (Swank 1958)
(7) -SE Yavapai County (Swank 1958)
(8) -North of Globe (Rich 1961)
(9,10,11,12) -(Tiedemann and Schmutz 1966)

[2]"--" indicates negligible.

Species	Total observed	Common occurrence
	(*Number*)	
Lizards (including Gila monster)	12	6
Snakes (including 2 rattlesnakes)	10	6
Birds	42	29
Bats	6	4
Rodents	5	4
Carnivores	6	2
Even-toed ungulates	2	2
	83	53

The carnivores are coyote, fox, black bear, ringtail cat, and two species of skunks. The even-toed ungulates are the collared peccary and whitetail deer.

Communities

The literature makes little mention of communities in the chaparral type. One probable reason for so little work having been done on this phase of chaparral ecology is that only a few species of shrubs are capable of dominating the cover over any sizable area. Swank (1958) took a step in the direction of community delineation by recognizing: (a) a shrub live oak-skunkbush sumac type in the drier portions of the chaparral, (b) a mixed shrub type to include most other combinations of shrub live oak and other species, and (c) nearly pure stands of manzanita or mountainmahogany. Manzanita in particular forms dense thickets of relatively large extent in certain areas of the chaparral (Nichol 1952). Darrow (1944) divided the chaparral and mountain browse type of Cochise county into four segments: (a) nolina, (b) mountainmahogany, (c) desert ceanothus, and (d) mixed shrubs.

It should be noted that, while the Arizona chaparral resembles the California chaparral in general character as a broad sclerophyll shrub community, and shares some of the same species, the major dominants (as well as the characteristic climates) are different (McGinnies 1972).

Lack of knowledge of how the characteristics of the various chaparral communities are related to productive potentials for range, wildlife, watershed, and recreation purposes seriously restricts the ability of land managers to plan action programs to achieve the improvements that are possible. Obtaining the basic information necessary for making these decisions should have high priority in any future research program in the chaparral type.

Morphologic and Phenologic

The Arizona chaparral type consists almost entirely of broad sclerophyll shrub communities, mostly of low-growing species with thick, evergreen leaves. The leaves of most species remain on the plants throughout the winter and until new leaves are well developed the following spring (Pond and Bohning 1971). Skunkbush sumac is an exception; its leaves are not thick and leathery, and are dropped following the first fall frosts.

Chaparral shrubs normally produce most of their growth in the spring. Summer growth is dependent on sufficient rain to recharge the soil water, and is thus spotty and not dependable (Swank 1958). Swank felt that available water was the primary factor controlling growth of chaparral shrubs, because the presence of leaves throughout the year permits photosynthesis almost whenever soil moisture is available. Reynolds (1967), however, reported that temperature appeared to control the beginning and ending of the growth period for shrub live oak, Wright silktassel, and mountainmahogany. Growth occurred when average daily temperatures were between 50° and 80°F (April to November). These observations suggest that growth periods are probably controlled by the interaction between temperature and soil moisture.

Major Shrub Species

Characteristics of the major shrub species are described by Dayton (1931), USDA-FS (1937), Swank (1958), and Pond and Bohning (1971) as follows:

Shrub live oak.—The most abundant shrub in the chaparral, this species usually grows 3 to 8 feet tall, but can grow to 15 feet with basal stems over 4 inches in diameter. It usually grows in clumps, often with thousands of individual stems from a single or more often several separate root crowns. A drought-resistant species, it grows from as low as 2,000 feet elevation to as high as 8,000 feet, but mostly between 4,500 and 6,000 feet. Root crowns contain thousands of inactive buds which can sprout following fire, or chemical or mechanical treatments that destroy the aboveground parts of the plant. Plants are long lived. Of eight plants tagged and photographed in 1920 on the Sierra Ancha Experimental Forest, only one died during the next 47 years (Pond 1971).

Because of the long-lived nature of shrub live oak, its vigorous sprouting capabilities, and its high natural resistance to damage by browsing, pests, and disease, few seedlings are needed to maintain a healthy stand. Seedlings are seldom found under natural conditions in most years. In favorable years,

seeds germinate and become established from late July to mid-September. Excavations of 3-year-old seedlings at Sierra Ancha (Pase 1969) showed that the plants averaged 2.9 inches tall, but roots had reached a depth of 21 inches. From examination of precipitation records, Pase hypothesized that successful oak seedling germination and establishment requires 15 inches or more of October-March precipitation followed by 10 inches or more of July-September rainfall. Precipitation records indicate that these requirements are met on the average of only 1 year in 10 at Sierra Ancha.

Although low in palatability, shrub live oak is an important source of forage for livestock and deer because of its abundance and its availability for emergency use during winters of heavy snow when other feed may be scarce. New succulent growth is readily grazed. Goats graze shrub live oak at all seasons. The acorns are relished by deer, wild turkey, and possibly by other wild game.

Mountainmahogany.—Three species of mountainmahogany grow in various parts of the Arizona chaparral. True mountainmahogany has the widest range, from South Dakota and Montana to New Mexico and Arizona. In Arizona, it prefers elevations from 4,500 to 7,000 feet. Birchleaf mountainmahogany is found in Arizona on the lower warmer slopes, from 3,000 to 6,500 feet, mostly in the chaparral. Hairy mountainmahogany has the most restricted range, western Texas to Arizona, and is found at higher elevations, 5,000 to 8,000 feet on dry slopes and mesas in the chaparral type. These species ordinarily grow to about 10 feet tall, but birchleaf and true mountainmahogany can reach 20 feet and hairy mountainmahogany 15 feet. These shrubs seldom form pure stands, but may dominate localized areas. They all sprout from root crowns following fire. They are important forage species for livestock and deer, and withstand heavy browsing very well, although in certain locations the palatabilities have been reported to be low.

Desert ceanothus.—Desert ceanothus ranges throughout the chaparral type, from 3,000 to 7,000 feet elevation, but more commonly at the lower elevations, and always in association with other species. It seldom exceeds 6 feet in height, and is relatively short lived. Desert ceanothus seldom sprouts after fire, but it produces seed every year from which new plants eventually become established. Although it is not as palatable for cattle as some other species, Swank (1958) rates it "at the top of the list of preferred foods" for deer. Unfortunately, it cannot withstand continuous heavy browsing, and is eventually eliminated on areas with large deer populations.

Manzanita.—Two species of manzanita are common in the Arizona chaparral—pointleaf and Pringle. Pringle manzanita is somewhat larger but less common than pointleaf. Pringle manzanita grows to about 6 feet tall, in large clumps which often grow so close together that they form nearly pure impenetrable thickets several hundred acres in extent. These species seldom sprout, but they can form new plants by layering wherever a stem touches the ground. Seeds are fire scarified, and seedlings quickly reoccupy burned areas. Manzanitas are practically worthless as forage for cattle and deer, although goats are reported to graze them freely, and the berries are used by bear and birds.

Skunkbush sumac.—Skunkbush sumac is the one common chaparral shrub that loses its leaves every fall. It is common throughout the type from 2,500 to 7,500 feet elevation, but seldom forms more than a few percent of the overstory. This plant grows to 7 feet tall, but averages about 4 feet. It sprouts vigorously from the root crown following fires. The plant is relatively long lived. The forage value of skunkbush sumac for livestock and deer is definitely low, in both palatability and nutritive value, although Chapline (1919) reports it to be of very high palatability for goats.

Hollyleaf buckthorn.—This shrub is common in the chaparral from 3,000 to 7,000 feet elevation, always in association with other shrubs. This species sprouts vigorously from the root crown after fire, grows rapidly, and is grazed readily by both cattle and deer. It withstands heavy use quite well, in part because it is able to grow beyond the reach of both cattle and deer.

Wright silktassel.—Wright silktassel, one of the taller chaparral shrubs (to 10 feet), is common throughout the type but most abundant from 5,000 to 8,000 feet. It varies from absent to locally very abundant. It sprouts rapidly from the root crown following fire, and grows vigorously. Swank (1958) reports that deer browse silktassel moderately, and that livestock prefer it to many other species. Chapline (1919) rates it moderately high in palatability for goats.

Cliffrose.—Cliffrose is found in the chaparral type and higher, between 3,000 and 8,000 feet, but it is most abundant at the higher elevations. It seems to prefer limestone-derived soils, but is also found on granitic, volcanic, and other igneous formations. It is a long-lived plant and ordinarily grows to a maximum of about 12 feet tall, but in the most favorable situations may reach 25 feet. Cliffrose is an important and valuable browse plant for sheep, cattle, and deer, particularly in winter; it is little used in spring and summer if other succulent forage is available.

Sugar sumac.—Also known as mountain laurel, this large shrub (to 15 feet tall) is found throughout the chaparral, but most abundantly between 3,000 and 5,000 feet elevation. It may become locally abundant, but usually occurs as scattered individuals. Pase and Johnson (1968) list it as occasional in the chaparral type at Sierra Ancha. Sugar sumac sprouts vigorously from the root crowns after fire, and the young sprouts are used heavily by deer. Mature growth is seldom used by deer or cattle.

Catclaw mimosa.—Catclaw mimosa (also called wait-a-bit) is a deciduous shrub of the semidesert shrub type and the lower parts of the chaparral type from 3,000 to 6,000 feet elevation, frequently in large dense thickets. It is relatively short, usually not more than 3 feet, but occasionally to 6 or 8 feet tall, and densely prickly with paired catclawlike prickles at the nodes on all stems. In its prickliness and deciduous character, catclaw mimosa is more semidesertlike than chaparrallike. This species sprouts profusely after fire. The younger, less prickly growth is sometimes grazed, and the pods are well liked by cattle, but the species is of strictly minor importance as forage for livestock and deer in the chaparral type.

Emory oak.—Emory oak grows as a shrub or small tree (to 50 feet tall under optimum conditions) on deep soils in the chaparral type. It also extends downward along watercourses to the uppermost edge of the desert and desert grassland (Benson and Darrow 1944) and upward into the oak woodland, from 3,000 to 8,000 feet elevation. On drier sites it occurs as scattered individuals of shrub size; on deeper soil and more mesic sites it may occur as groves of small to medium trees (Pase 1969). Emory oak sprouts and grows vigorously from the root crown following fire. Livestock and deer make little use of this species for forage (Swank 1958).

Litter Production

At Sierra Ancha, three-fourths of the litterfall from shrub live oak accumulates from April through August. About 90 percent of the litter consisted of leaves; catkins, twigs, bark, and acorns made up the remainder (Pase 1972). Litter was shed rather uniformly (10 to 15 percent per month) on north slopes during the 5 months, but on south slopes 47 percent of the litter fell during April and May. December and January were the lowest yielding months on both exposures. For the chaparral community as a whole, the peak litterfall was during summer (44 percent of the annual total), followed by winter and spring (20 percent each), and fall (16 percent).

Litter yield from shrub live oak is high, relative to its crown cover, while litter yield from pointleaf manzanita, skunkbush sumac, and desert ceanothus is low (Kemp 1965). The total weight of the forest floor under nine caged shrub live oaks averaged 8,200 pounds per acre for the north exposure and 14,600 pounds per acre on the south exposure. The depth of the forest floors averaged slightly over 1 inch (Pase 1972), representing between 5 and 10 years' accumulation of annual litter. The lower weights on the north slope are probably an indication of a considerably higher rate of decomposition due to the more mesic conditions.

More dense stands (85 to 95 percent canopy cover) of shrub live oak and Pringle manzanita at Sierra Ancha, and of manzanita alone in the Mazatzal Mountains, showed total forest floor weights of 24,200 and 22,400 pounds per acre, respectively (Garcia and Pase 1967). A dense, mature, nearly pure stand of Pringle manzanita in central Arizona yielded 41,277 pounds of litter per acre, with an average depth of 1.4 inches (Glendening and Pase 1964). These heavier weights are probably the result of heavier annual yields from the more dense stands, and much slower decomposition.

Research is needed to determine the variability in the amount and distribution of litter in the chaparral type and its effect on erosion rates.

Successional Pattern

According to Darrow (1961) the present-day chaparral type in Arizona apparently had its beginnings during the Miocene Epoch of the Tertiary Period of the Cenozoic Era. It was a Madro-Tertiary Flora of semiarid woodland and thorn scrub vegetation, which in late Miocene and early Pliocene times extended from California to Oklahoma and Texas. As the climate differentiated during this period, in response to continued uplift and orogeny in the southern Rocky Mountains and westward, the vegetation segregated itself also, and by mid-Pliocene times the formerly continuous chaparral belt had divided into a California segment and a Southwestern segment. The Arizona chaparral type is about all that remains of the Southwestern segment, and it apparently has been here for several million years—obviously a climax formation. Clements (1928) stated that "the chaparral formation constitutes a real climax, though portions of it are undoubtedly subclimax."

Stages Represented

Examples of chaparral extending beyond its normal climatic limits into pine or woodland types due

to periodic burning, or into grassland due to prolonged heavy grazing by cattle, are properly referred to as subclimaxes (Clements 1936, Weaver and Clements 1938). Saunier (1964) concluded that, rather than representing past or present invasions, the small islands of shrub live oak surrounded by grassland common in the vicinity of Prescott and also at Sierra Ancha represent relicts of a formerly continuous stand. A combination of drought, fire, and somewhat less favorable soil moisture conditions has eliminated the oaks from the intervening spaces.

Fires, both natural and man-caused, burn periodically in the Arizona chaparral. However, Pase (1972) described one chaparral area that had not burned for at least 74 years. Baldwin[3] estimates the ages of some chaparral stands (since the last fire) at 80 to 100 years. He also estimates that burned chaparral areas left to recover naturally will not support a repeat burn for at least 20 years. If the burned area is reseeded to grasses, however, and a good stand is established, the area can burn again in 4 or 5 years. If 6 or 7 years elapse, the recovering shrub stand will have eliminated most of the grasses and another 15 or 20 years may pass before the area will support another fire.

It thus appears likely that little true chaparral climax remains, and that essentially the entire type has been burned over periodically. The type is not a fire climax, however, in the sense that fire is necessary to maintain it. The chaparral is a true climatic climax, but unusually susceptible to large-scale burning.

A single fire causes little retrogression in the chaparral climax because most of the dominant shrub species sprout readily from the root crown, and those that do not usually produce abundant seed that are stimulated to sprout by the fire. Thus, the chaparral stands tend to recover relatively rapidly following fire. There may be some changes in total shrub cover and in relative crown cover due to differences in the rapidity with which the various species sprout, and to the relative advantage of the sprouters over the nonsprouters in reoccupying the area. The density and composition of the understory is often changed also, with the advantage to the shrubs (Schmutz and Whitham 1962).

Crown cover generally recovers most rapidly during the first 3 years (up to 10 percent per year), gradually slowing as the cover approaches preburn levels (table 2) (Pase and Pond 1964). More than 11 years are required for the shrub cover to reach preburn levels (Hibbert et al. 1974) (fig. 5). Rates of recovery of individual shrub species vary with their inherent sprouting ability or seedling establishment ability, with their relative abundance in the preburn stand, and possibly with the time of year of the fire. Because of the competitive advantage of sprouts over seedlings, the relative crown covers of the strong sprouting species generally increase and that of the weak or nonsprouters decreases following fire, sometimes drastically.

The forb stage in the secondary succession after fire reaches a peak in the second or third growing

[3]*Personal communication with Mr. Joy Baldwin, Fire Control Officer, Tonto National Forest, Phoenix, Arizona.*

Table 2.--Percent composition of chaparral on Mingus Mountain, based on line intercepts, following June 1956 burn (Pase and Pond 1964)

Species	1956	1957	1958	1960	1961
			Percent		
Shrub live oak	81.0	80.4	63.4	70.5	68.0
Skunkbush sumac	11.3	12.9	14.8	9.2	9.0
Catclaw mimosa	5.7	2.7	3.2	2.2	2.4
Broom snakeweed	0	T	7.2	11.5	11.8
Hairy mountain-mahogany	.4	1.4	2.1	1.6	2.3
Desert ceanothus	T	T	.4	1.4	1.8
Manzanita:					
Pringle	0	0	.4	1.6	2.0
Pointleaf	0	.1	.2	.2	.4
Others	1.5	2.6	2.4	1.8	2.4
Total	100.0	100.0	100.0	100.0	100.0
Shrub cover	4.8	16.2	28.6	37.6	41.7

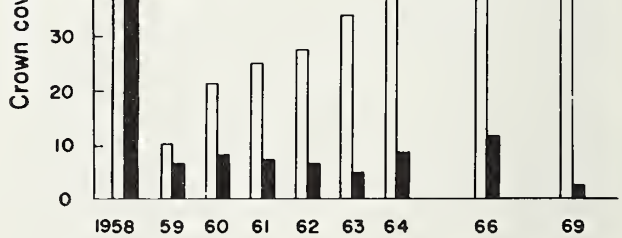


Figure 5.—Shrub recovery at Three Bar watersheds following 1959 wild fire: Natural recovery on watershed D; shrub sprouts suppressed with herbicides on watershed C (from Hibbert et al. 1974).

season and then declines rapidly (table 3) (Pase and Pond 1964). Grasses are only slightly more permanent, usually reaching their peak in the fifth to the seventh year. The decrease in herbaceous understory after fire is attributed to increasing competition from the rapid shrub sprout and seedling growth, probably aggravated by increased grazing pressure on the remaining herbaceous plants as their abundance declines. (See also Swank 1958, Glendening et al. 1961, Hibbert 1971.)

Table 3.--Production of grasses and forbs on Mingus Mountain, upper and lower areas, burned in June 1956 (Pase and Pond 1964)

Area	1956	1957	1958	1960	1961
	- - - *Pounds/acre* - - -				
Upper area:					
Grasses	4	16	141	196	157
Forbs	T	22	259	127	22
Total	4	38	400	323	179
Lower area:					
Grasses	T	40	57	56	97
Forbs	0	15	28	31	8
Total	T	55	85	87	105

A comparison of seedling numbers 1 year after a planned October burn in the Mazatzal Mountains gives some indication of the relative seedling-producing ability of several common chaparral species (Pase 1965). Although the area burned was a dense manzanita community with a nearly "closed" canopy and only minor amounts of shrub live oak and desert ceanothus, seedlings of several species appeared on the burned area. Narrowleaf yerba-santa, Pringle manzanita, and desert ceanothus produced the largest numbers of seedlings, but five other species also appeared (table 4). The appearance of yerba-santa was completely unexpected, because it was totally absent from the mature stand; the seedlings apparently came from seed stored in the soil, perhaps for many years. Seedling appearance of all species was strongly (for most species, totally) dependent on the fire, and for most species a higher intensity of burn resulted in greatly increased numbers of seedlings compared to a light burn. On the unburned check area, only yellowleaf silktassel and Emory oak produced seedlings, but in fewer numbers than on the burned area.

Table 4.--Surviving 1-year-old seedlings (plants per acre) on El Oso Burn (Pase 1965)

Species	Burned October 1962		Unburned check
	Intense burn	Light burn	
	- - *Number* - -		
Pringle manzanita	18,180	4,363	0
Desert ceanothus	2,618	636	0
Deerbrush	190	0	0
True mountainmahogany	95	0	0
Narrowleaf yerba-santa	101,293	16,453	0
Yellowleaf silktassel	571	1,182	59
Emory oak	143	364	118
Shrub live oak	48	91	0

Present Condition

Guides for evaluating the condition of Arizona chaparral ranges for livestock grazing have been developed by Rigden and Parker (1943), and Humphrey (1964). The main consideration in these guides is the relative abundance and productivity of desirable perennial grasses in the openings. Additional factors considered include the density of the shrub stand, presence of palatable shrubs, evidence of active erosion, and indicators of heavy grazing (fig. 6).

In terms of productivity for range livestock, the condition of much of the chaparral is not good. Even in 1941, McGinnies et al. noted that ". . . within the last 30 years fire and too heavy grazing have greatly increased the density (of shrubs) and encouraged encroachment of this type into adjacent types . . ."; and ". . . perennial grasses . . . were at one time more abundant than at present," especially blue, black, hairy, and side-oats gramas, dropseeds, three-awns, curly mesquite, bluestems, and wolftail.

Nichol (1952) stated that "Unless much broken by sod patches of considerable extent the type as a whole is poor range land." Rigden and Parker (1943) observed "There is much evidence that snakeweed as well as the larger shrubs has increased in density since the advent of grazing, whereas the herbaceous ground cover has become badly depleted over much of the type." Pond[4] noted that the perennial grass cover in the chaparral type was generally sparse, as reflected by the stocking rates of from 2 to 15 animals per section yearlong on the Tonto and Prescott National Forests.

Some isolated tracts of chaparral in the southeastern part of the State, on the other hand, appear to be in better condition. Humphrey (1960) noted that the chaparral type in the mountain foothills of the southeastern part of the State "usually grows

[4] *Pond, Floyd W. 1962. Range management research in the Arizona-New Mexico chaparral—a project analysis and working plan. (Typewritten report on file at Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.)*

A

Figure 6.—
A, Chaparral range in excellent condition. High density and production of understory grasses, primarily side-oats and hairy gramas and curly mesquite.

B

B, Chaparral in poor condition. Herbaceous understory sparse and erosion active.

more grass and, consequently, produces more forage than it does farther north in the State" possibly due to regional differences in rainfall distribution.

Guides for evaluating chaparral areas for wildlife habitat, recreational use, and water yield potential are not available, and should be developed.

HISTORICAL DEVELOPMENT

Settlement of the chaparral area lagged some years behind that of the areas to the north and south because of the very rough topography. During the 1860's prospectors and traders accompanied Government troops on scouting trips within the chaparral type (Croxen 1926). During this period, several military posts were established within the type to prevent raids by the numerous Indian tribes that inhabited most of the territory (Lockwood 1932).

Prospecting and mining led to the earliest settlements within the chaparral type, such as Prescott, established in 1863, and Globe in 1873 (Barnes 1935). As reports of large areas of nutritious grasses spread outside the territory, settlers began bringing in livestock. In 1874 the first cattle were brought to the Tonto Basin country a few miles southeast of Payson. Within the next 10 years or so most of the type was stocked, primarily with cattle, but with a few bands of sheep and some goats (Croxen 1926). At this time, apparently, the shrub stands were quite open, with excellent stands of grass interspersed.

The Tonto Forest range was fully stocked with livestock by about 1890, but the peak stocking was not reached until about 1900. At this time there were 15 to 20 times as many cattle on the range as were present in 1926 (Croxen 1926), when stocking rates were presumably nearer true carrying capacity. One of the principal reasons for the drastic decline in stocking was an 18-month drought in 1903-04, which resulted in severe death loss on the overstocked and depleted ranges. By 1926 many of the areas that had been covered with stirrup-high grass stands 50 years earlier were dense stands of brush.

RANGE MANAGEMENT PRACTICES

Deciding Proper Grazing Use

Kind of Animal

The Arizona chaparral is now grazed almost exclusively by cattle. However, experience in other parts of this country and in other countries strongly suggests that goats or goats and cattle would produce greater returns in meat and other products than cattle alone, and would help control certain species of brush. As late as 1942, in fact, an estimated 210,000 angora goats, grazing mostly on the chaparral ranges in the central part of the State, produced over 1 million pounds of mohair (Rigden and Parker 1943).

Goats would help maximize returns from the chaparral because of the inherent differences in grazing habits between goats and cattle. McGinnies et al. (1941) state that ". . . cattle ordinarily will show a marked preference for grass but will make some use of weeds and shrubs. On the other hand, goats will make the greatest use of browse but to some extent will consume both grasses and weeds."

There are, however, subtle interactions between kind of grazing animal and productivity of the vegetation that depend on season of use, relative abundance of grasses and shrubs, species of shrubs present, intensity of use, and soil and climatic factors that should be considered before deciding on a specific kind or mix of animals.

On the Edwards Plateau in Texas, dual use by cattle and goats returned \$4.75 gross per acre per year over a 20-year period, compared to \$3.29 by cattle alone (Merrill et al. 1966, Merrill 1969). Goats would be particularly valuable for keeping sprouts grazed down on areas where fire or chemical shrub control treatments have been applied. This would permit a more productive grass cover to develop and provide a suitable forage mix for dual use by goats and cattle.

Number of Animals

Rates of stocking of chaparral ranges must be carefully adjusted to the available forage. This basic requirement is probably more important on chaparral ranges than on some others because of the strong competitive effects of shrubs. Too heavy grazing on interspersed grasses in poor vigor can cause rapid deterioration of the grass stand and invasion of broom snakeweed and other low-value plants. Too heavy browsing can also kill out the palatable shrubs (Rigden and Parker 1943). Humphrey (1964) recommends leaving at least one-fourth of the current year's twig growth at the end of the season. McCulloch (1955, as reported by Swank 1958) suggests that use should not exceed 30 to 35 percent of the current twig growth on most browse species.

Rich and Reynolds (1963) suggest that utilization of 40 percent of perennial grass production on chaparral lands characterized by an interspersion of shrubs and perennial grasses will enable the grasses to maintain a vigorous condition and provide adequate protection for the soil. They also state that chaparral lands in good condition have a grazing capacity of 5 to 15 acres per cow month (about 4 to 11 head per section yearlong). Humphrey (1960) suggests carrying capacity for chaparral range may

vary from none to 15 head per section yearlong. Animal numbers are particularly important when cattle and sheep or cattle and goats are grazed on the same range, so that their numbers are balanced with the preferred forage for each (Rigden and Parker 1943).

Season of Grazing

Yearlong grazing is usual in the chaparral type because of the relatively mild climate and the presence of evergreen browse plants which provide forage and shelter during snowy periods (Rigden and Parker 1943). Chaparral is particularly well suited to yearlong use because of the differences in seasonal growth patterns between shrubs and grasses: the shrubs are more succulent and thus more palatable in spring (their main period of growth) than in summer, and the grasses are more palatable in summer (their main period of growth). Some chaparral ranges are especially valuable for fall-winter-spring grazing (Rich and Reynolds 1963).

Grazing Systems

Research on grazing systems for Arizona's chaparral ranges has been extremely limited. As a general recommendation for rangeland in Yavapai county, Humphrey (1964) suggests summer deferment every other year for deteriorated ranges, and once every 3 to 5 years for ranges in excellent condition.

In one field trial, the range was divided into four pastures for a rotation-deferred grazing system on an operating ranch in the chaparral type west of Prescott (Freeman 1961). All the cattle were kept in one pasture, and use of the pastures was rotated so that no pasture was grazed more than half of any one growing season or at the same season in any 2 successive years. After 2 years of operation the benefits of the plant were reported as (1) ease of looking after the cattle in a single herd, (2) increased vigor of perennial grasses, (3) perennial grasses establishing near watering places and in gullies, and (4) more even utilization resulting from salting away from water. After the first 2 years, the system was expanded to include the forest allotment as a five-pasture system. The system appears to be flexible enough to take care of variable grass production; use of major species was held to about 50 percent. The emphasis was on grass management, and no mention was made of shrub use.

Improving Forage Production

Seeding

Reseeding is a valuable tool in improving the condition and forage production of chaparral ranges, but all research indicates that the shrub stand must be severely reduced because of excessive competition between chaparral shrubs and grass seedlings.

In detailed recommendations for seeding in the chaparral type (Ariz. Agric. Exp. Stn. 1969), the type is subdivided into three environmental zones: (1) the Mohave chaparral, consisting of the lower, mountainous, northwest portion; (2) the Coronado chaparral, consisting of the isolated areas that surround mountain ranges in the southeastern part of Arizona; and (3) the Mogollon chaparral, containing the bulk of the type, that lies below the Mogollon Rim, between the other two zones. The Mohave and Mogollon portions are further subdivided into two precipitation ranges each, and recommendations are made for upland and bottomland sites in each of the type subdivisions.

The species recommended ". . . have been evaluated in many experimental and field plantings, . . . can be established with relative ease, . . . are persistent and maintain vigor under proper grazing management, . . . are available in commercial seed channels, . . . and have good forage value in the area where they are adapted." Sixteen species—two legumes (alfalfa, and yellow sweetclover) and 14 grasses—have a wide range of adaptability, but a few are very restricted. Lcvegrasses and wheatgrasses dominate the grass recommendations (table 5). Interestingly, the most successful species tested by Lavin and Pase (1963), King Ranch bluestem, is not mentioned in the Experiment Station bulletin although a closely related species, Turkestan bluestem, is mentioned as showing promise but needing additional trials and field evaluation plantings.

The general recommendations for successful reseeding mentioned include:

- Use seed of adapted species only.
- Select areas with good potential for supporting a good cover (do not seed shallow or rocky soils or excessively steep slopes).
- Prepare a suitable seedbed reasonably free from competition of undesirable plants (control competing plants by mechanical, chemical, or burning treatments).
- Distribute seed evenly, cover at proper depth, and compact the soil around the seed. Drilling is the preferable method, especially with large-seeded species, but broadcast seeding often gives satisfactory results, particularly with small-seeded species.
- Protect the seeded area until the stand is established.

Table 5.--Species recommended for seeding on upland (upper) and bottomland (lower) sites in various portions of the chaparral type

Species	MOHAVE ZONE Precipitation of--				MOGOLLON ZONE Precipitation of--				CORONADO ZONE Precipitation	
	12-14 inches		14-16 inches		14-18 inches		18-30 inches		of 17-20 inches	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Alfalfa				X		X	X	X		X
Yellow sweetclover		X	X	X	X	X	X	X	X	X
Sand dropseed	X	X								
Black grama	X		X		X				X	
Blue grama			X	X	X	X			X	X
Boer lovegrass	X	X	X	X	X	X			X	X
Lehmann lovegrass	X	X	X	X	X	X			X	X
Weeping lovegrass		X	X	X	X	X	X	X	X	X
Indian ricegrass	X	X	X	X	X	X				
Crested wheatgrass	X	X	X	X	X	X	X	X		
Intermediate wheatgrass				X		X	X	X		
Pubescent wheatgrass		X	X	X	X	X	X	X		
Siberian wheatgrass	X	X	X	X	X	X				
Western wheatgrass		X		X	X	X	X	X		
Spike muhly					X	X	X	X		
Tall fescue								X		
Orchardgrass							X	X		
Perennial ryegrass							X	X		

Reseeding trials following accidental chaparral fires in the Pinal and Mazatzal Mountains of central Arizona indicate that: (1) Weeping lovegrass establishes itself easily and can yield as much as 1,600 pounds per acre by the third year. However, it usually declines thereafter. The decline is due in part to increasing competition from the recovering shrubs, but since it also takes place on some shrub-free areas in the chaparral type, a nutrient deficiency may also be involved (Cable 1957, Pond and Cable 1962, Pond 1968). (2) Of 16 species of cool-season forbs and cool- and warm-season grasses, only Lehmann lovegrass and King Ranch bluestem rated good or excellent after the third growing season. Turkestan bluestem, weeping lovegrass, and black and Indian mustards rated fair. Buffelgrass was the most vigorous species the first year, but was not coldhardy enough to withstand the winters. Lehmann lovegrass maintained itself better than weeping lovegrass, but is not coldhardy enough for many chaparral sites (Lavin and Pase 1963).

One phase of reseeding research has been almost completely neglected in Arizona—seeding or planting palatable shrubs to improve forage conditions for livestock and wildlife. Such research should have a priority because of the important wildlife and recreation potential of chaparral areas. Considerable research of this kind has been conducted in Utah (Plummer et al. 1968).

Plant Control

Control of undesirable shrubs not only is necessary to sucessful reseeding of grasses on chaparral ranges, but it also increases water yields and can benefit wildlife. The numerous methods of shrub control tried on chaparral ranges in Arizona can be grouped into several categories (Ariz. Agric. Exp. Stn. 1969, Hibbert et al. 1974):

- Mechanical—cabling, chaining, railing, flailing, mowing, root plowing, bulldozing.
- Burning.
- Chemical.
- Biological—plant pests, grazing animals.
- Combinations of one or more of the above.

Mechanical methods.—Most of the mechanical methods are not well adapted to chaparral. Methods such as cabling and chaining destroy only the aboveground parts of the plants; root crowns of most chaparral species then sprout prolifically. Bulldozing, which is effective in uprooting isolated clumps of shrubs, is a desirable method where a good understory of perennial grasses is present between the shrub clumps (Ariz. Agric. Exp. Stn. 1969).

Root plowing is the most effective mechanical method for controlling chaparral shrubs. This method involves pulling a heavy blade, attached

horizontally to a crawler tractor (fig. 7), at a depth of from 8 to 18 inches in the soil (Pond and Bohning 1971). The Arizona Agricultural Experiment Station (1969), recommends a minimum depth of 12 inches for shrub live oak. The depth of the blade should be based on the type of root system of the dominant shrub present and on the soil type. The blade should be pulled just below the root crown (sprouting bud zone), so that it separates all roots from the root crown and lifts the severed plants out of the ground.

A

B

Figure 7.—
A, Tractor with 12-foot-wide root-plow blade.
B, In operation, grass seed is broadcast from rear of tractor.

Large rocks, gullies, and steep slopes severely restrict the area on which root plowing can be used. Pond (1961) estimates that 2 to 8 percent of the chaparral type can be safely root plowed. Where the root plow can be used, however, from 81 to 95 percent or more of the chaparral shrubs can be killed (Pond 1961, Pond et al. 1965), and grass production can be increased tremendously by seeding adapted species (fig. 8). Root plowing on relatively level chaparral should cost $20 to $25 per acre, and seeding behind the plow $5 or less per acre, depending on species and current seed costs.

Figure 8.—Root-plowed area at Tonto Springs, Prescott National Forest, reseeded to weeping and Lehmann lovegrasses. (Photo by Ray Manley.)

Even on low-elevation ranges on granitic soils, removal of shrubs and seeding to Lehmann and Boer lovegrasses can greatly reduce erosion and increase forage production. At the Summit watersheds (elevation about 3,800 feet), grubbing shrubs and seeding grass increased grass basal area by 10 times and reduced erosion more than 99 percent in the following 7 years (Rich 1961) (fig. 9).

Burning.—Prescribed burning has been studied intermittently for many years as a possible method for controlling chaparral shrubs and creating openings in the stands. The natural fire resistance of several chaparral shrubs, particularly shrub live oak, was clearly demonstrated at Sierra Ancha, where five successive annual burnings were required to reduce the number of shrub live oak sprouts below preburn numbers (Pond and Cable 1960).

Burning must be combined with other types of control to improve forage production. Prescriptions for planned broadcast burning to kill the aboveground parts of chaparral shrubs, with minimum damage to herbaceous understory and the soil, have been developed by the Southwest Interagency Fire Council (1968). The SWIFCO guide indicates fall is the recommended season for burning chaparral in the Southwest. This is the period of high fire danger, but not so high that prescribed fires cannot be controlled. Within this season, conditions of humidity, wind, and fuel moisture can be prescribed that

A

Figure 9.—Summit watersheds 6 (left) and 7 (right).
A, In 1936.

B

B, In 1960, 7 years after grubbing shrubs and seeding to Lehmann and Boer lovegrasses.

will produce a fast-moving fire with least damage to understory herbaceous vegetation and soil.

Specifications for successful chaparral burns (fig. 10) include:

- Vegetation must be dormant or nearly dormant.
- Wind should not exceed 4 miles per hour.
- Relative humidity should be between about 14 and 35 percent, with fuel stick moisture between about 8 and 18 percent.

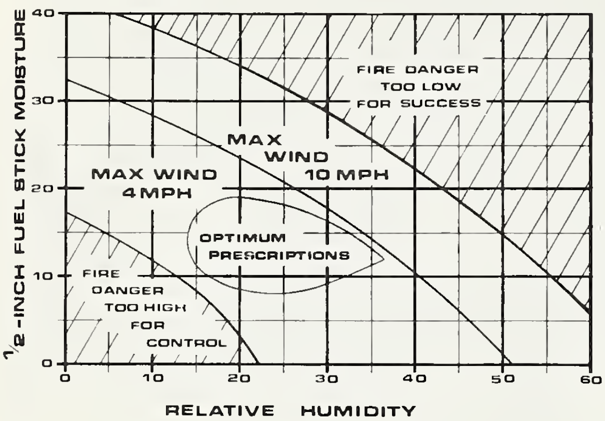


Figure 10.—Current recommendations for successful prescribed burning in Arizona chaparral (reprinted from Southwest Interagency Fire Council 1968).

Burning can be successful under more humid conditions if the vegetation has been treated with chemical desiccants to dry out the foliage (risk of escape would also be less under these conditions). In trials at Sierra Ancha, spraying a mixture of 2,4-D and 2,4,5-T 4 to 6 weeks prior to burning dried the shrub foliage to a little over 10 moisture (from about 90 percent), and the subsequent September burns topkilled most of the shrubs. These fires consumed from 22 to 51 percent of the litter, which left the soil better protected than a completely clean burn (Lindenmuth and Davis 1962, Lindenmuth and Glendening 1962, Pase and Glendening 1965, Pase and Lindenmuth 1971).

Burning a converted chaparral area in February (7 years after root plowing and seeding), when soil moisture was high and grass and leaf bases were relatively moist, resulted in a flashy fire that effectively topkilled shrub sprouts but did not harm the grass stand (primarily Lehmann lovegrass, and Turkestan and King Ranch bluestems) (Pase 1971). This type of burning, repeated periodically, might well offer a relatively cheap method of suppressing shrub growth on converted chaparral areas.

Chemical treatments.—Most research in the use of chemicals for chaparral control has concentrated on shrub live oak, because it is the major dominant over most of the type and one of the most difficult species to kill. Until recently, the phenoxy herbicides 2,4,5-T and silvex were the most effective chemicals available. Even with repeated annual applications, however, the more resistant species continued to sprout from the root crown (Lillie and Davis 1961, Lillie 1962, Lillie 1963, Pase 1967, Davis and Pase 1969).

Picloram (a picolinic acid) and fenuron (a substituted urea) appear to offer considerably more promise than the phenoxys. Lillie and Davis (1961) note that pelleted fenuron (25 percent active ingredient) not only killed mature oak when applied to field plants at 16 pounds per acre, but also that it killed all grasses and forbs. Pelleted fenuron applied by hand under channelside shrubs and trees at the Whitespar watersheds southwest of Prescott, at the rate of 23.2 pounds acid equivalent per acre (for shrub area actually treated), resulted in effective control. It was estimated (Ingebo 1971) that the single application of fenuron ". . . probably will eventually kill 80 percent or more of the chaparral cover, even the highly resistant shrub live oak." Because the intershrub spaces were not treated, the native grasses and forbs ". . . have exhibited renewed vigor since the elimination of competition."

More recently, karbutilate and bromacil have shown much promise for shrub control in experimental trials. Broadcast in the form of large pellets several feet apart, these materials adequately control the shrubs with minimum damage to understory grasses (Hibbert et al. 1974).

Much research has been conducted on the effects of herbicides on fire sprouts. Such data probably have general applicability to unburned chaparral, although the larger more woody stems of unburned plants are more difficult to kill than are the tender stems of fire sprouts (Lillie and Davis 1961). In general, fire sprouts of the more resistant chaparral shrubs are difficult to kill even with repeated applications of 2,4,5-T.

Fenuron and picloram exhibited different degrees of selectivity when applied as pellets to 6-year-old sprouts of five shrub species (fenuron at 18 pounds per acre of ground actually treated and picloram at 9 pounds per acre). At the end of the third growing season, the percent shrub kills were as follows (Davis and Pase 1969):

	Shrubs killed with — Fenuron	Picloram
	(Percent)	
Shrub live oak	82	56
Palmer oak	40	23
Birchleaf mountainmahogany	54	94
Sugar sumac	57	100
Yellowleaf silktassel	20	100

The differential susceptibilities, and the relatively high kills obtained, provide numerous possibilities for manipulating chaparral cover by using particular combinations of the two herbicides to favor or control specific species. Even more selectivity could be obtained by hand application or use of a low-flying helicopter. Spot application of pellets also minimizes damage to stands of understory grasses between the shrubs.

The available data suggest that many burned chaparral areas can produce 800 to 1,000 pounds of native and seeded perennial grasses per acre, if crown cover of sprouting shrubs can be held to less than 5 to 10 percent by chemical or other means.

Biological methods.—Biological methods of controlling undesirable vegetation include use of insect pests, competing vegetation, and browsing animals. No insect pests are known that are sufficiently destructive to control our chaparral shrubs. Also, since the less desirable shrub species are usually the more aggressive ones, they cannot be crowded out by the desirable species. Use of browsing animals, however, particularly goats, does offer some possibilities for shrub control. For example, Davis et al. (1975) describe how goats have been used successfully in Colorado to control Gambel oak sprouts. Management systems that include goats to graze the young shrub sprouts after an initial prescribed burn should be tested. A rotation-deferred grazing system designed around the relative forage contribution of grasses and shrubs and the seasonal grazing preferences of cattle and goats will be needed to provide optimum harvest of each class of forage. Periodic reburning may also be needed to topkill the shrubs and provide more succulent browse.

This kind of management system would be applicable to a large portion of the chaparral type. Grass seed can be broadcast aerially, and steep slopes offer no great barrier to grazing by goats.

Combination treatments.—Combination treatments generally produce better results, in terms of improving forage production, than single treatments.

(1) Fire-chemical. One of the big advantages of a combination of prescribed burning and use of chemicals is that these treatments can be applied on most of the chaparral type, regardless of topography. Reseeding also must be included in many of these combination treatments to obtain optimum herbaceous production, however. Initial results from one pilot-scale trial in central Arizona indicate an increase of 1,500 pounds of forage per acre and a reduction in fire hazard and fire suppression costs (Suhr 1967).

(2) Mechanical-chemical. The most successful combination treatment that did not involve burning consisted of control of sprouts after root plowing with spot applications of fenuron at 12 pounds per acre in December. Root-plowed and seeded pastures supported about three times as many cattle per acre as the chaparral pastures during the first 3 years after treatment. Yearlings on chaparral pastures produced 10.8 pounds of beef per acre per year, compared to 40.0 pounds per acre on root-plowed and seeded pastures (Pond 1967).

Numerous other combinations of control treatments are possible (fig. 11). Because the least expensive conversions involve fire as an initial treatment, burning has been proposed as the initial treatment in most chaparral-to-grass conversions (Courtney and Baldwin 1964, Proctor 1971). How-

Figure 11.—Mechanical - chemical - burning treatments to convert chaparral to grass at Three-Bar:

A, Good stand of Lehmann lovegrass after root plowing and fenuron treatment (January 1969).

B, March 1969, after prescribed burn to control shrub sprouts. Unburned check plot in right background.

ever, any combination treatment to control chaparral shrubs and improve forage production must also consider grazing management. For example, an initial burn followed by reseeding of adapted grasses will generally result in a stand of grass and shrub sprouts. A proper rotation grazing system, then, would provide for goats to keep the shrub sprouts under control and cattle to harvest the grass. It might be necessary to reburn periodically to maintain minimum shrub competition.

Economic and Other Benefits of Conversion

Selection of specific areas of chaparral for conversion to grass must involve the economics of conversion as well as effects of other wildland values.

Few land managers will spend money on a range improvement practice without assurance that the benefits will at least pay for the cost of the treatment. Few cost-benefit analyses have been made for range improvement practices in the chaparral. However, a recent report by Brown et al. (1974) estimates costs and benefits to be expected from converting 139 specific areas in the Salt-Verde Basin best adapted to conversion from chaparral to grass. They indicate average annual per-acre benefits of 0.21 foot of additional runoff, 0.24 additional AUM of grazing, and a 34-cent reduction in fire fighting costs. These benefits add up to a net average annual return of $2.51 per converted acre, based on the best estimates of benefits on areas with more than 30 percent shrub cover and slopes less than 60 percent. Benefit-cost ratios varied from 0.1 to 6.4 on the 139 areas, and were 1.0 or greater on 96 areas. Other alternative conversion treatments gave lower benefits. While the cost and benefit values used in this analysis will change with time and may not apply exactly to any specific area, the methodology provides a means of evaluating the economic feasibility of chaparral-to-grass conversions.

The appearance of converted areas must also be considered. Openings must be designed so that they blend naturally with the landscape. Within these economic and esthetic constraints, benefits in the forms of increased grazing for domestic livestock and wildlife, and increased water yields and recreation opportunities can be expected from chaparral conversion. These benefits are discussed at appropriate places in the report.

Fertilizer Applications

Range fertilization is in the experimental stage in Arizona—it is not a common practice. Research to date indicates that addition of nitrogen provides the best response generally, with no essential difference between the different forms of nitrogen (Ariz. Agric. Exp. Stn. 1969). Addition of phosphorus or potassium has not significantly increased forage yields (Gary and Rich 1961). Other studies suggest that fertilizer may be beneficial on bottomland and upland sites in all three subdivisions of the Arizona chaparral type (Ariz. Agric. Exp. Stn. 1969). However, the necessity of adequate precipitation following fertilization, and the frequent lack of adequate summer precipitation, considerably restricts the chances for success. With adequate precipitation, grass production has increased up to 2.2 times (Anklam 1962, Bales 1965). Also, increased quality and palatability usually accompany increases in production. The present state of the art is such that no general recommendations are available for fertilizer application on chaparral range.

Increasing Usability of the Range

Water Development

Developments of permanent water in the chaparral type, largely by livestock interests, have consisted mostly of spring improvement (headboxes and troughs), and to a lesser extent, windmills and earth tanks. Swank (1958) states that "The development of free water has been rather extensive in Arizona chaparral" and estimates that not more than 15 percent of the chaparral range is more than 1 mile from water during the dry season.

For optimum distribution of cattle grazing in rough terrain, a rule-of-thumb guide is that cattle should not have to travel more than ¼ to ½ mile to water (USDA-SCS 1967). Under present conditions of relatively low forage production in most of the chaparral type, the present distribution of watering places may approach adequacy. However, after treatment to improve forage production and with more intensive management, additional water developments might be necessary. On the other hand, limited experience with chaparral conversion to grass, (e.g. Brushy Basin on the Tonto National Forest, Suhr 1967) indicates that many previously intermittent streams become permanent following conversion.

One promising technique in the field of rangeland water development is the horizontal well. Of 58 horizontal wells drilled on the San Carlos Indian Reservation in central Arizona (several on chaparral-type land), 51 produced water; length varied from 31 to 273 feet (average 97 feet), and cost varied from $190 to $735 (average $361.64) complete (Ariz. Cattle Growers' Assoc. 1969). (See also Welchert and and Freeman 1973.)

Fencing

Dividing the range into suitably sized parcels,—based on availability of water, uniformity of topography and vegetation, class of livestock, and kind of grazing system used—is one of the most effective methods of obtaining proper distribution of grazing use (Stoddard and Smith 1955, USDA-SCS 1967). If sheep and goats are herded, fences are not needed. However, an increasing scarcity of competent herders has been a strong factor in the decline of sheep and goat numbers in Arizona. If cattle and sheep or goats are grazed together without herding, more pastures and better fences will probably be required than for cattle alone. Proper location of fences is especially important in the chaparral type (Freeman 1961, Suhr 1967).

Salt Placement

Proper placement of salt helps to obtain more uniform distribution of grazing use. Location of salt grounds in the chaparral type should follow the same principles as for other types (Stoddart and Smith 1955, USDA-SCS 1967):

- Pick openings in the brush on ridges or gentle slopes.
- Do not place salt at water or in low swales or other places where livestock naturally congregate.
- Salting in areas with species of low palatability will increase their utilization.
- In rough terrain, salt grounds should be not over ½ to 1 mile apart.
- Locations should be changed every year or two, or whenever the desirable forage plants show damage from trampling and grazing.

Salting away from water has been rather difficult to sell to many ranchers because of the belief that cattle like to drink after salting. However, this belief has been disproved in numerous instances, and salting away from water is becoming much more widespread. Freeman (1961) reports that a central Arizona rancher, when initiating a deferred-rotation grazing system in the chaparral type, also placed salt away from water (first about 1/8 mile, then ½ mile or farther). Salting away from water and changing salt grounds frequently encouraged cattle to graze away from water, and livestock distribution became more uniform.

Riding

Riding or herding is the most positive method of obtaining uniform distribution of livestock grazing, but it is also relatively expensive in labor cost and cannot be depended on to keep cattle in hilly areas if flatter areas are nearby.

Trail Construction

Use of graded trails in hilly and mountainous country often offers an opportunity to utilize areas that livestock would not be able to reach otherwise. This is particularly true with cattle; sheep and goats can be herded to most usable areas with little difficulty. Good trails can reduce use of steep slopes near watering facilities. Graded trails reduce the grazing use of nearby steep slopes by providing easy access to usable feed areas somewhat farther from water (Hendricks 1939, Stoddart and Smith 1955, USDA-SCS 1967).

Managing the Livestock

Nutrition

Proper nutrition of the grazing animals is vital to attaining optimum production on any range. Nutritive values and digestibility have been investigated in some detail for deer in the Arizona chaparral. Swank (1958) showed that protein content of shrubs averaged 15.1 percent during the spring growing period (April) in the Prescott area, and 12.8 percent in the Pinal Mountain area. On both areas, protein content averaged around 7 percent in July, January, and March. Mountainmahogany and desert ceanothus, both desirable species, showed the highest yearlong protein content, with hollyleaf buckthorn, also a desirable species, close behind. The two species of manzanita and Utah juniper, undesirable species, showed the lowest yearlong average protein content, with shrub live oak and most other shrub somewhat higher. Protein content of sprouts (some to 5 years old) on burned areas was higher than for those on adjacent nonburned areas.

Phosphorus content of shrubs was also highest during the spring growing period (0.32 and 0.25 percent on Prescott and Pinal Mountain areas, respectively) (Swank 1958). Phosphorus content gradually decreased to about 0.13 percent for the July, January, and March samples.

Analyses of first-year fire sprouts of shrub live oak, Wright silktassel, and birchleaf mountainmahogany for a 1-year period (1963-64) at Sierra Ancha (Reynolds 1967) showed a seasonal pattern of change in protein and phosphorus similar to that shown by Swank, but the levels were somewhat lower for both elements. Also, these data show a minor peak in late August corresponding to the summer regrowth period (there was no summer regrowth in 1954-55 on Swank's areas). The mountainmahogany showed the highest protein content and silktassel the lowest. Calcium trends were erratic seasonally and among species. As shown in other studies, crude protein and moisture content were linearly and directly related for all species.

McCulloch and Urness (1973) present detailed data on white-tailed and mule deer at all seasons of the year in the chaparral. They found that by selective grazing of plant parts and species, both deer maintained a relatively uniform level of protein throughout the year, adequate for growth and reproduction.

Nutritive studies with domestic livestock on chaparral are limited. In a study near Prescott, however, Pond (1967) reported that (1) monthly gains by yearling steers were greater on range seeded to weeping lovegrass than on chaparral from March through November, (2) cattle held their own on chaparral but not on grass in January and February, and (3) steers lost weight on both chaparral and grass in December.

Protection

Livestock on the range must be protected from a variety of hazards including predators and inclement weather. One benefit of chaparral, briefly alluded to previously, is that it provides protection for cattle as well as available forage during periods of extreme snowfall. In one such instance, following 50 inches of snow at Tonto Springs west of Prescott, 15 calves survived unattended for 12 days in a dense chaparral stand, even though they lost about 40 pounds each. On grass pastures in the vicinity, 4 head (of 195) died even though they had all been rescued the second day and fed hay for the rest of the period (Pond et al. 1968). Pond estimated that heavy snowfalls (although not as heavy as that of 1967) can be expected in about 1 year in 10.

Operational Costs and Returns

No detailed economic analyses of ranching operations in the chaparral type could be found in the literature. However, as with other ranching areas in the State, the unfavorable investment return under current land prices compared with other investment opportunities makes ranching for economic return unattractive. The appeal of ranching as a way of life, though, appears to be of sufficient value to enough people that livestock ranching will continue to be a major use on all range areas in the State for the foreseeable future (Smith and Martin 1970).

Overall averages for Yavapai County, where nearly half of the chaparral type in Arizona occurs, show carrying capacity of all rangeland to be about 10 head per section yearlong. Assuming production of one calf per cow year, worth about $150, and a land value of $3,000, the value of the calf represents a 5 percent gross return. Production expenses would use up about half of this return, leaving only 2½ percent return on the investment (Hayes 1971). For suitable range on the Tonto and Prescott National Forests, using the same valuations, the average proper stocking rate of 9 head per section yearlong would yield a net return on the investment of 2 percent.

Correlating Grazing with Other Uses

Water

The chaparral type, in its present condition, does not contribute heavily to the water yield in Arizona. Streamflow of a series of chaparral watersheds averaged 1 inch, compared to from 2.4 to 6.5 inches for watersheds in the ponderosa pine type and 3.3 inches in mixed conifer (Brown 1970). Yields from a watershed in the juniper type averaged 1 inch, the same as a chaparral watershed.

Despite the low water yield from untreated chaparral watersheds, yields following conversion to grass have approached those of the pine-fir and mixed conifer sites (Hibbert and Ingebo 1971). The large increases presumably result from reduced transpiration when deep-rooted shrubs are replaced by shallow-rooted grasses and forbs that use less water (Hibbert 1971). Yield increases from chaparral-to-grass conversions have varied from none on dry sites with open stands of chaparral (Rich 1961) to more than 6 inches (an increase of five times pretreatment yield) on wet sites under dense shrub stands (Hibbert and Ingebo 1971).

These differences in response to chaparral removal are related to total precipitation, to the character of the shrub stand, and to the degree of weathering and fracturing of the substratum. Dense shrub stands on weathered or fractured substrata which enable water (and shrub roots) to penetrate relatively deeply (20 to 40 feet) have high potential for increased water yield with conversion to grass. Sparse shrub stands where substrata are little weathered and fractured have low potential for increased water yield.

Water yield in the chaparral type occurs largely in the winter and spring; 85 percent of the yearly total is produced from November to April. The increase following conversion to grass follows this same pattern, so that most of the increase would be expected to reach a point of use (Hibbert and Ingebo 1971). Runoff data indicate a strong relation between mean annual precipitation and the expected increase in water yields. Little increase can be expected if annual precipitation is less than 17 inches, but for each additional inch of mean precipitation, water yield increases about 0.74 inch (Hibbert et al. 1974) (fig. 12).

The size of the increase in water yield following shrub conversion also depends on the proportion of the shrub cover removed. If shrubs are thinned,

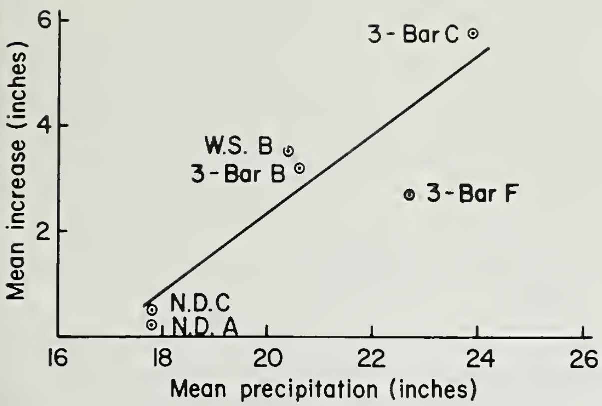


Figure 12.—Mean annual increase in water yield as a function of mean annual precipitation for experimental watersheds at Sierra Ancha, Whitespar, and Three-Bar (from Hibbert et al. 1974).

water yields will increase little—between 10 and 20 percent—for the first 50 percent of shrubs removed. Yields increase faster for later increments of shrub removal, as shown hypothetically in figure 13 (Hibbert et al. 1974).

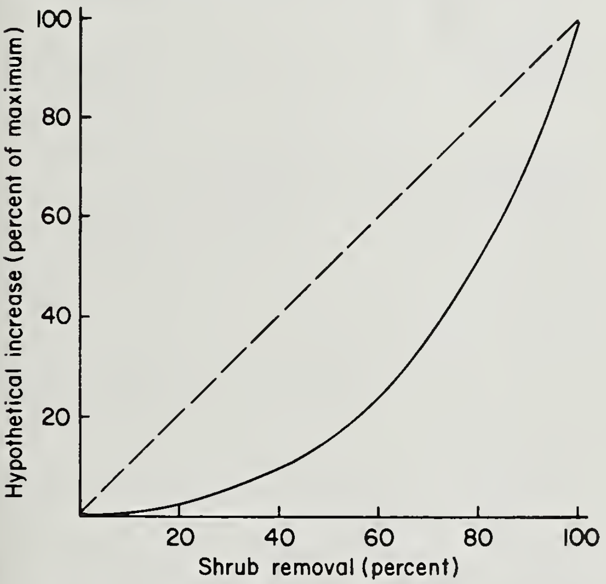


Figure 13.—Hypothetical increase in water yield as a function of percent of shrub cover removed in a thinning operation (from Hibbert et al. 1974).

The value of conversion to grass can be relatively high. For example, an estimated 1.6 inch increase in water yield from 3,000 acres amounts to 400 acre-feet per year, or at $20 per acre-foot, a value of $8,000 per year. When benefits from increased livestock forage and reduced fire hazard are added, total benefits amount to $97 per acre over a 10-year period, against $30 per acre for cost of burning and chemical treatments (Suhr 1967, Brown and Boster 1974).

Sediment movement from dense natural chaparral is negligible, except for the rare unusually large, intense storm. Whenever the shrub cover is removed, as by fire, the protection of the shrub canopy is temporarily lost. Depending on the extent of damage to the litter cover, the unstable soils are exposed to the full impact of high-intensity summer storms. About 85 percent of the onsite soil movement on chaparral watersheds is carried by summer storms. Following a destructive wildfire that burned the Three-Bar watersheds in June 1959, sediment yields increased to 20,000 tons per square mile (about ¼ inch off the watershed). Sediment movement declined sharply as cover reestablished, and by the fourth postfire year, sediment yield was approaching the very low prefire levels (Pase and Ingebo 1965, Pase 1966). Sediment yields decreased fastest on a watershed where lovegrasses were seeded and shrub sprouts were suppressed by chemicals.

The runoff from summer storms is of short duration, and the sediment does not normally move very far. Winter runoff redistributes the sediments accumulated in the channels. Extreme precipitation events that come at intervals of several years flush out the builtup accumulations (Boster and Davis 1972).

Water-yield considerations have provided the major impetus for research on chaparral-to-grass conversions. However, the treatments that yield the largest increases in water yield also result in large increases in usable livestock forage. And along with the improvements in the water and grazing resource, wildlife and recreation values can be greatly improved with little or no loss to water and grazing values.

Wildlife

Wildife research in the chaparral type has been primarily concerned with deer. The desert mule deer ranges in the lower part of the chaparral type (to about 4,000 feet elevation) while white-tailed deer range from 3,000 feet upward (Urness et al. 1971).

Deer populations in Arizona chaparral vary from 4 to 5 per square mile in the drier areas, where shrub live oak and skunkbush sumac predominate, to 20 to 30 per square mile in the higher, wetter areas of mixed shrubs (Swank 1958). Deer populations are relatively low where the brush is dense and herbaceous understory is sparse. Urness (1974) found that deer spent ½ to ¼ as much time on chaparral areas cleared by plowing as in untreated brush. But he suggests the deer probably received much more

benefit per unit of time on the cleared areas because of the relatively high volumes of high-quality forages (especially forbs), and because deer spent their time on these areas exclusively for feeding (they rested, ruminated, etc. on untreated areas).

The extent of competition between deer and cattle for herbaceous plants in the chaparral is not known, but probably is not serious, even though they generally prefer the same shrub species. In fact, the browse forage used by cattle probably far exceeds the herbaceous forage used by deer. All authorities agree that livestock and wildlife would both benefit from opening up the chaparral stand. Because of their need for escape cover, however, the optimum amount of clearing for deer would probably be much less than for cattle (Swank 1958, Pond and Bohning 1971, Urness et al. 1971).

Most chaparral treatments result in an increase in production of young, nutritious sprouts. This is especially true of treatments such as periodic burning, in which each treatment results in a renewal of sprout production and more browse forage for both livestock and deer.

Management plans for chaparral must provide not only enough browse for deer, but adequate escape cover as well. Although optimum patterns of brush and grass have not been investigated thoroughly, Urness (1974) suggests that some brush should be left on all slope aspects. Control areas can be of any length, but should not exceed about 300 to 400 yards in width, and probably no more than 50 percent of any area should be treated.

EMERGING DEMANDS FOR THE RESOURCE

In its present unimproved state, the chaparral type is used relatively little by the hunter and recreationist, primarily because the brush is thick, roads are few, and access is difficult. As openings are created in the chaparral, use by hunters and picnickers has increased. Thus it appears that good management for water, forage, and wildlife can be good recreational management as well.

SUMMARY AND EVALUATION

The 3 to 6 million acres of chaparral in Arizona constitute a valuable range resource that is being used far below its productive potential. Use and management of this resource are difficult because of the great diversity in environmental conditions (soils, slopes, elevations, precipitation, temperature, and other characteristics), and because of the great complexity of vegetation: a large number of shrubby species of varying productivity and palatability are present in many combinations in a wide range of densities, and with widely varying herbaceous understories.

Limited research and pilot trials involving conversions of chaparral to grass have shown that such conversions result in greatly increased grass and livestock production, greatly increased water yield, reduced fire hazard and fire suppression costs, and improved wildlife and recreation values.

Optimum management of the chaparral range requires:

• Improvement in the production of forage and opening of the stand by treatments designed to:
1. Convert areas to grass, to provide interspersion and diversity of chaparral stands.
2. Maintain portions of the shrub component in a young-sprout stage rather than a mature stage.
3. Modify the shrub composition toward more palatable plants and fewer unpalatable plants.

• Improvement in range and livestock management by:
1. Designing grazing systems to meet the physiological needs of the native and introduced forage species.
2. Developing management techniques for dual use by cattle and goats on the same range.

Technical information needed to accomplish improvements and increased use in chaparral type includes:

• Development of a habitat type classification and associated management implications.
• Refined prescriptions for using fire as a tool for controlling sprout growth or maintaining it in a young, nutritious condition through timing and frequency of reburning, necessary amounts of fuel, and so forth.
• More selective chemicals to increase the usefulness of chemical shrub control, and particularly how these treatments affect herbaceous and desirable browse cover.
• Additional seeding and planting methods for herbaceous and shrubby species that can be used on a wider variety of sites.
• Grazing systems to properly utilize the chaparral type in its present unimproved condition in conjunction with areas converted to grass.

Necessary complementary research would provide information on: (1) how to measure shrub production, (2) what levels of use the various species of shrubs can tolerate, (3) how season of use affects grass and shrub production, (4) seasonal patterns of physiological development of the major forage species, and (5) changes in grazing use of shrub sprouts with age of sprouts.

LITERATURE CITED

Anklam, George L.
1962. The effects of commercial fertilizers on the forage production of chaparral lands in central Arizona following burning, reseeding, and herbicide treatments. M.S. thesis. Univ. Ariz., Tucson. 32 p.

Arizona Agricultural Experiment Station.
1965. Arizona natural vegetation. Ariz. Agric. Exp. Stn., Bull. A-45 (map).

Arizona Agricultural Experiment Station.
1969. Guide to improvement of Arizona rangeland. Ariz. Agric. Exp. Stn. Bull. A-58, 93 p.

Arizona Cattle Growers' Association.
1969. Range management society tours: Gila grass and water. Ariz. Cattlelog 27(4):8-9.

Bales, Robert Lee.
1965. Ecology of a cleared chaparral site under different nutrient treatments. M.S. thesis. Univ. Ariz., Tucson. 117 p.

Barnes, Will C.
1935. Arizona place names. Univ. Ariz. Gen. Bull. 2, 503 p.

Benson, Lyman, and Robert A. Darrow.
1944. A manual of southwestern desert trees and shrubs. Univ. Ariz. Biol. Sci. Bull. 6, 411 p.

Biswell, H. H.
1954. The brush control problem in California. J. Range Manage. 7:57-62.

Boster, Ron S., and Lester R. Davis.
1972. Soil-loss considerations in chaparral-to-grass conversions. Natl. Symp. on Watersheds in Transition Proc., Am. Water Resour. Assoc. Ser. 14, p. 243-250.

Brown, Harry E.
1970. Status of pilot watershed studies in Arizona. ASCE J. Irrig. Drain. Div. 96(IR1):11-23.

Brown, Thomas C., and Ron S. Boster.
1974. Effects of chaparral-to-grass conversion on wildfire suppression costs. USDA For. Serv. Res. Pap. RM-119, 11 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Brown, Thomas C., Paul F. O'Connell, and Alden R. Hibbert.
1974. Chaparral conversion potential in Arizona. Part II: An economic analysis. USDA For. Serv. Res. Pap. RM-127, 28 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Cable, Dwight R.
1957. Recovery of chaparral following burning and seeding in central Arizona. U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn., Res. Note 28, 6 p. Fort Collins, Colo.

Chapline, W. R.
1919. Production of goats on far western range. U.S. Dep. Agric. Bull. 749, 35 p.

Clements, Frederic E.
1928. Plant succession and indicators. 453 p. H. W. Wilson, Co., N.Y.

Clements, Frederic E.
1936. Nature and structure of the climax. J. Ecol. 24(1):252-284.

Courtney, R. E., and J. J. Baldwin.
1964. Modifying chaparral brushland on the Tonto National Forest to improve multiple resources values. Proc. 8th Annu. Ariz. Watershed Symp., p. 31-35. [Phoenix, Ariz.]

Croxen, Fred W.
1926. History of grazing Tonto. Tonto Grazing Conf., Phoenix, Ariz., Nov. 1926. 12 p.

Darrow, Robert A.
1944. Arizona range resources and their utilization in Cochise County. Ariz. Agric. Exp. Stn. Tech. Bull. 103, p. 332-335.

Darrow, Robert A.
1961. Origin and development of the vegetational communities of the Southwest. **In** Bioecology of the arid and semiarid lands of the Southwest. N.M. Highlands Univ. Bull., Cat. Iss., p. 30-47.

Davis, Edwin A., and Charles P. Pase.
1969. Selective control of brush on chaparral watersheds with soil-applied fenuron and picloram. USDA For. Serv. Res. Note RM-140, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Davis, Gary G., Lawrence E. Bartel, and C. Wayne Cook.
1975. Control of Gambel oak sprouts by goats. J. Range Manage. 28(3):216-218.

Dayton, William A.
1931. Important western browse plants. U.S. Dep. Agric., Misc. Publ. 101, 214 p.

Fletcher, J. E., and E. L. Beutner.
1941. Erodibility investigations on some soils of the upper Gila watershed. U.S. Dep. Agric., Tech. Bull. 794, 32 p.

Freeman, John D.
1961. Society members develop grazing plan. J. Range Manage. 14(2):70-71.

Garcia, R. M., and C. P. Pase.
1967. Moisture-retention capacity of litter under two Arizona chaparral communities. U.S. For. Serv. Res. Note RM-85, 2 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Gary, Howard L., and Lowell R. Rich.
1961. Nitrogen aids plant growth on Arizona soils derived from granite and diabase. U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn., Res. Note 57, 2 p. Fort Collins, Colo.

Glendening, George E., and C. P. Pase.
1964. Effect of litter treatment on germination of species found under manzanita (*Arctostaphylos*). J. Range Manage. 17(5):265-266.

Glendening, G. E., C. P. Pase, and P. Ingebo.
1961. Preliminary hydrologic effects of wildfire in chaparral. Proc. 5th Annu. Ariz. Watershed Symp., p. 12-15. [Phoenix, Ariz.]

Hanson, W. E., and Clay Y. McCulloch.
1955. Factors influencing mule deer in Arizona brushlands. Trans. 20th North Am. Wildl. Cong., p. 568-588.

Hayes, John.
1971. Private enterprise and rural land. Ariz. Cattlelog 28(9):6,8-10,12-13.

Hendricks, B. A.
1939. Graded trails as an aid in the distribution of cattle on rough ranges. U.S. Dep. Agric., For. Serv., Southwest For. and Range Exp. Stn., Res. Note 67, 2 p. Tucson, Ariz.

Hibbert, Alden R.
1971. Increases in streamflow after converting chaparral to grass. Water Resour. Res. 7(1):71-80.

Hibbert, Alden R., Edwin A. Davis, and David G. Scholl.
1974. Chaparral conversion potential. Part I: Water yield response and effects on other resources. USDA For. Serv. Res. Pap. RM-126, 36 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Hibbert, Alden R., and Paul A. Ingebo.
1971. Chaparral treatment effects on streamflow. Proc. 15th Annu. Ariz. Watershed Symp., p. 25-34. (Ariz. Water Comm. Rep. 1, Phoenix, Ariz.)

Humphrey, Robert R.
1960. Forage production on Arizona ranges. V. Pima, Pinal, and Santa Cruz Counties. Ariz. Agric. Exp. Stn. Bull 302, 138 p.

Humphrey, Robert R.
1964. Arizona range resources. II. Yavapai County. Ariz. Agric. Exp. Stn. Bull. A-35, 55 p.

Ingebo, Paul A.
1971. Suppression of channel-side chaparral cover increases streamflow. J. Soil Water Conserv. 26(2):79-81.

Kearney, Thomas H., and Robert H. Peebles.
1951. Arizona flora. 1032 p. Univ. Calif. Press, Berkeley and Los Angeles.

Kemp, Kenneth.
1965. A study of litter and vegetation in the upper chaparral area of central Arizona. M.S. thesis. Univ. Ariz., Tucson. 79 p.

Lavin, Fred, and Charles P. Pase.
1963. A comparison of 16 grasses and forbs for seeding chaparral burns. U.S. For. Serv. Res. Note RM-6, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Lillie, D. T.
1962. Herbicide combinations for control of shrub live oak. Res. Prog. Rep., West Weed Control Conf. Proc. 1962:17-18.

Lillie, D. T.
1963. Control of Arizona chaparral with 2,4,5-T and silvex. J. Range Manage. 16(4):195-199.

Lillie, D. T., and E. A. Davis.
1961. Chemicals for control of chaparral. Proc. 5th Annu. Ariz. Watershed Symp., p. 9-11. [Phoenix, Ariz.]

Lindenmuth, A. W., Jr., and James R. Davis.
1962. Chemical treatment helps burn brush safely in Arizona. Timberman 43(7):9.

Lindenmuth, A. W., Jr., and G. E. Glendening.
1962. Controlled burning of Arizona chaparral—a 1962 progress report. Proc. 6th Annu. Ariz. Watershed Symp., p. 23-24. [Phoenix, Ariz.]

Lockwood, Frank C.
1932. Pioneer days in Arizona. 387 p. Macmillan Co., New York.

McCulloch, Clay Y.
1955. Ecological investigation of Three-Bar study area. Comp. Rep. Proj. W-71-R-3, Work Plan 4, Ariz. Game and Fish Dep., Wildl. Restoration Div., 10 p. Phoenix, Ariz.

McCulloch, Clay Y., and Philip J. Urness.
1973. Deer nutrition in Arizona chaparral and desert habitats. Ariz. Game and Fish Dep., Spec. Rep. 3, 68 p.

McGinnies, William G.
1972. Continental aspects of shrub distribution, utilization, and potentials—North America. **In** Wildland shrubs—Their biology and utilization. USDA For. Serv. Gen. Tech. Rep. INT-1, p. 55-66. Ogden, Utah.

McGinnies, W. G., K. W. Parker, and G. E. Glendening.
1941. Southwestern range ecology. U.S. Dep. Agric., For. Serv., Southwest. For. and Range Exp. Stn., 211 p. Tucson, Ariz.

Merrill, Leo B.
1969. Grazing systems in the Edwards Plateau of Texas. Am. Soc. Range Manage. [Calgary, Alberta, Can., Feb. 1969] Abstr. of Pap. 22:22-23.

Merrill, Leo B., Patrick O. Reardon, and C. L. Leinweber.
1966. Cattle, sheep, goats . . . mix 'em for higher gains. Tex. Agric. Prog. 12(4):13-14.

Nichol, A. A.
1952. The natural vegetation of Arizona. Ariz. Agric. Exp. Stn., Tech. Bull. 127, p. 189-230.

Pase, Charles P.
1965. Shrub seedling regeneration after controlled burning and herbicidal treatment of dense Pringle manzanita chaparral. U.S. For. Serv. Res. Note RM-56, 2 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Pase, C. P.
1966. Grazing and watershed value of native Arizona plants. In Native plants and animals as resources in arid lands of the southwestern United States. Am. Assoc. Adv. Sci., Rocky Mt. Southwest. Div. [Comm. Desert Arid Zones Res., Flagstaff, Ariz., May 1965] Contrib. 8, p. 31-40.

Pase, C. P.
1967. Helicopter-applied herbicides control shrub live oak and birchleaf mountainmahogany. U.S. For. Serv. Res. Note RM-84, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Pase, C. P.
1969. Survival of *Quercus turbinella* and *Q. emoryi* seedlings in an Arizona chaparral community. Southwest. Nat. 14(2):149-155.

Pase, Charles P.
1971. Effect of a February burn on Lehmann lovegrass. J. Range Manage. 24(6):454-456.

Pase, Charles P.
1972. Litter production by oak-mountainmahogany chaparral in central Arizona. USDA For. Serv. Res. Note RM-214, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Pase, C. P., and Martin M. Fogel.
1967. Increasing water yield from forest, chaparral, and desert shrub in Arizona. Int. Conf. Water for Peace Proc., v. 2, p. 753-764. [Wash., D.C., May 1967].

Pase, C. P., and George E. Glendening.
1965. Reduction of litter and shrub crowns by planned fall burning of oak-mountainmahogany chaparral. U.S. For. Serv. Res. Note RM-49, 2 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Pase, C. P., and P. A. Ingebo.
1965. Burned chaparral to grass: early effects on water and sediment yields from two granitic soil watersheds in Arizona. Proc. 9th Annu. Ariz. Watershed Symp., p. 8-11. [Phoenix, Ariz.]

Pase, Charles P., and R. Roy Johnson.
1968. Flora and vegetation of the Sierra Ancha Experimental Forest, Arizona. USDA For. Serv. Res. Pap. RM-41, 19 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Pase, Charles P., and A. W. Lindenmuth, Jr.
1971. Effects of prescribed fire on vegetation and sediment in oak-mountain mahogany chaparral. J. For. 69:800-805.

Pase, Charles P., and Floyd W. Pond.
1964. Vegetation changes following the Mingus Mountain burn. U.S. For. Serv. Res. Note RM-18, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Plummer, A. Perry, Donald R. Christensen, and Stephen B. Monsen.
1968. Restoring big-game range in Utah. Utah Div. Fish and Game Publ. 68-3, 183 p.

Pond, Floyd W.
1961. Mechanical control of Arizona chaparral and some results from brush clearing. Proc. 5th Annu. Ariz. Watershed Symp., p. 39-41. [Phoenix, Ariz.]

Pond, Floyd W.
1964. Response of grasses, forbs, and halfshrubs to chemical control of chaparral in central Arizona. J. Range Manage. 17:200-203.

Pond, Floyd W.
1967. Conversion of chaparral and shrub hardwood to productive range. Proc. Herbic. Veg. Manage. For., Ranges, and Noncrop Lands Symp., p. 214-219. [Corvallis, Oreg., Sept. 1967.]

Pond, Floyd W.
n.d. [1969]. Grazing values on undisturbed chaparral versus areas converted to grass: The Tonto Springs Range. U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn. Unnumbered Publ., 13 p. Fort Collins, Colo.

Pond, Floyd W.
1971. Chaparral: 47 years later. USDA For. Serv. Res. Pap. RM-69, 11 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Pond, Floyd W., and John W. Bohning.
1971. The Arizona chaparral. Ariz. Cattlelog 27(10):16,18,20,22-28; 27(11):13-16,18-24.

Pond, Floyd W., and Dwight R. Cable.
1960. Effect of heat treatment on sprout production of some shrubs of the chaparral in central Arizona. J. Range Manage. 13:313-317.

Pond, Floyd W., and Dwight R. Cable.
1962. Recovery of vegetation following wildfire on a chaparral area in Arizona. U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn., Res. Note 72, 4 p. Fort Collins, Colo.

Pond, Floyd W., James L. Kukal, and Eddie Balmes.
1968. Chaparral: a good cow home during deep snow. Ariz. Cattelog 16(2):17,18,20,22.

Pond, Floyd W., D. T. Lillie, and H. R. Holbo.
1965. Shrub live oak control by root plowing. U.S. For. Serv. Res. Note RM-38, 2 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Proctor, George.
1971. The Forest Service chaparral management policy. Proc. 14th Annu. Ariz. Watershed Symp., p. 39-40. [Phoenix, Ariz.]

Reynolds, Hudson G.
1967. Chemical constituents and deer use of some crown sprouts in Arizona chaparral. J. For. 65(12):905-908.

Reynolds, Hudson G., and R. Roy Johnson.
1964. Habitat relations of vertebrates of the Sierra Ancha Experimental Forest. U.S. For. Serv. Res. Pap. RM-4, 16 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Rich, Lowell R.
1961. Surface runoff and erosion in the lower chaparral zone—Arizona. U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn., Stn. Pap. 66, 35 p. Fort Collins, Colo.

Rich, Lowell R., and Hudson G. Reynolds.
1963. Grazing in relation to runoff and erosion on some chaparral watersheds of central Arizona. J. Range Manage. 16:322-326.

Rigden, J. T., and K. W. Parker.
1943. Guides to condition of Arizona chaparral goat ranges. Ariz. Stockman 9(10):4,10,11,13, 15.

Saunier, Richard Eugene.
1964. Factors affecting the distribution of shrub live oak (*Quercus turbinella*). M.S. thesis. Univ. Ariz., Tucson. 95 p.

Schmutz, Ervin M., and David W. Whitham.
1962. Shrub control studies in the oak-chaparral of Arizona. J. Range Manage. 15:61-67.

Seller, William D., ed.
1960. Arizona climate. n.p. Inst. Atmos. Phys., Univ. Ariz., Tucson.

Smith, Arthur H., and William E. Martin.
1970. Cattle ranching—a business or a way of life? Ariz. Cattlelog 27(1):22-24,26-29.

Southwest Interagency Fire Council.
1968. Guide to prescribed fire in the Southwest. 58 p. Univ. Ariz., Tucson.

Stoddart, Laurence A., and Arthur D. Smith.
1955. Range management. 433 p. McGraw-Hill, New York.

Suhr, Wes.
1967. Watershed action program—Tonto National Forest. Proc. 11th Annu. Ariz. Watershed Symp., p. 20-24. [Phoenix, Ariz.]

Swank, Wendell G.
1958. The mule deer in Arizona chaparral. Ariz. Game and Fish Dep. Wildl. Bull. 3, 103 p. Phoenix.

Tiedemann, Arthur R., and Ervin M. Schmutz.
1966. Shrub control and reseeding effects on the oak chaparral of Arizona. J. Range Manage. 19:191-195.

Urness, Philip J.
1974. Deer use changes after root plowing in Arizona chaparral. USDA For. Serv. Res. Note RM-255, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Urness, Philip J., Win Green, and Ross K. Watkins.
1971. Nutrient intake of deer in Arizona chaparral and desert habitats. J. Wildl. Manage. 35:469-475.

U.S. Department of Agriculture, Forest Service.
1937. Range plant handbook. n.p. U.S. Gov. Print. Off., Wash., D.C.

U.S. Department of Agriculture, Soil Conservation Service.
1967. National handbook for range and related grazing lands. 84 p. U.S. Gov. Print. Off., Wash., D.C.

Weaver, John E., and Frederic E. Clements.
1938. Plant ecology. 2d ed. 601 p. McGraw-Hill, New York.

Welchert, W. T., and Barry N. Freeman.
1973. 'Horizontal' wells. J. Range Manage. 26:253-256.

Wilson, Eldred D.
1962. A resume of the geology of Arizona. Ariz. Bur. Mines Bull. 171, 140 p.

COMMON AND BOTANICAL NAMES OF PLANTS MENTIONED

Common Name	Botanical Name
	Annual Grasses
Red brome	*Bromus rubens* L.
	Perennial Grasses
Black grama	*Bouteloua eriopoda* Torr.
Blue grama	*Bouteloua gracilis* (H.B.K.) Lag.
Bluestems	*Andropogon* spp.
Boer lovegrass	*Eragrostis chloromelas* Steud.
Buffelgrass	*Pennisetum ciliare* (L.) Link
Bullgrass	*Muhlenbergia emersleyi* Vasey
Crested wheatgrass	*Agropyron cristatum* (L.) Gaertn.
Curly mesquite	*Hilaria belangeri* (Steud.) Nash
Deergrass	*Muhlenbergia rigens* (Benth.) Hitchc.
Dropseed	*Sporobolus* spp.
Green sprangletop	*Leptochloa dubia* (H.B.K.) Nees
Hairy grama	*Bouteloua hirsuta* Lag.
Indian ricegrass	*Oryzopsis hymenoides* (Roem. & Schult.) Ricker
Intermediate wheatgrass	*Agropyron intermedium* (Host.) Beauv.
King Ranch bluestem	*Andropogon ischaemum* var. King Ranch
Lehmann lovegrass	*Eragrostis lehmanniana* Nees
Little bluestem	*Andropogon scoparius* Michx.
Longtongue mutton bluegrass	*Poa longiligula* Scribn. & Williams
Lovegrass	*Eragrostis* spp.
Orchardgrass	*Dactylis glomerata* L.
Perennial ryegrass	*Lolium perenne* L.
Plains lovegrass	*Eragrostis intermedia* Hitchc.
Pubescent wheatgrass	*Agropyron trichophorum* (Link) Richt.
Sand dropseed	*Sporobolus cryptandrus* (Torr.) A. Gray
Side-oats grama	*Bouteloua curtipendula* (Michx.) Torr.
Siberian wheatgrass	*Agropyron sibericum* (Willd.)
Spike muhly	*Muhlenbergia wrightii* Vasey
Squirreltail	*Sitanion* spp.
Tall fescue	*Festuca arundinaceae* Schreb.
Tall threeawns	*Aristida hamulosa* Henr. and *A. ternipes* Cav.
Threeawn	*Aristida* spp.
Turkestan bluestem	*Andropogon ischaemum* L.
Weeping lovegrass	*Eragrostis curvula* (Schrad.) Nees
Western wheatgrass	*Agropyron smithii* Rydb.
Wheatgrass	*Agropyron* spp.
Wolftail (Texas timothy)	*Lycurus phleoides* H.B.K.
	Forbs and Half Shrubs
Alfalfa	*Medicago sativa* L.
Black mustard	*Brassica nigra* (L.) Koch
Broom snakeweed	*Gutierrezia sarothrae* (Pursh.) Britt. & Rusby
Indian mustard	*Brassica juncea* (L.) Cosson
Purslane	*Portulaca* spp.
Spurge	*Euphorbia* spp.
Toadflax penstemon	*Penstemon linarioides* A. Gray
Wright eriogonum	*Eriogonum wrightii* Torr.
Yellow sweetclover	*Melilotus officinalis* (L.) Lam.

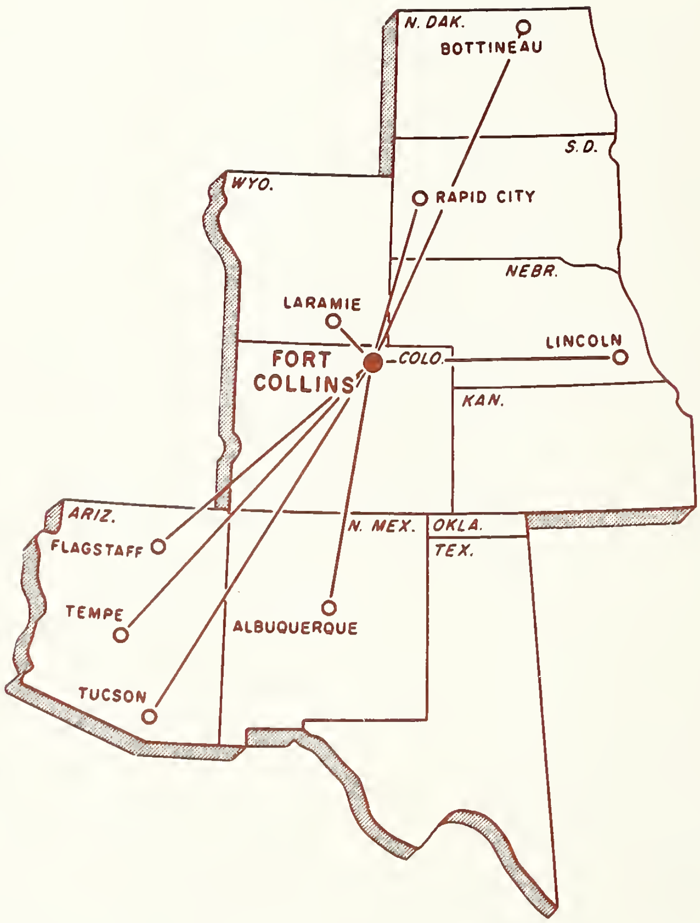
Although this report discusses research involving pesticides, such research does not imply that the pesticide has been registered or recommended for the use studied. Registration is necessary before any pesticide can be recommended. If not handled or applied properly, pesticides can be injurious to humans, domestic animals, desirable plants, fish, and wildlife. Always **read** and **follow** the directions on the pesticide container.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE



N. DAK.
BOTTINEAU
S. D.
WYO.
RAPID CITY
NEBR.
LARAMIE
LINCOLN
FORT COLLINS
COLO.
KAN.
ARIZ.
N. MEX.
OKLA.
TEX.
FLAGSTAFF
TEMPE
ALBUQUERQUE
TUCSON